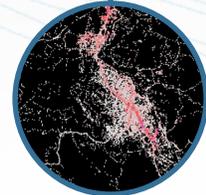
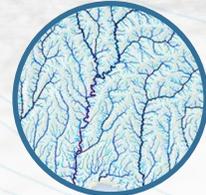


MS4 CATCHMENT DELINEATION AND ATTRIBUTE GENERATION GUIDANCE

VERSION 2, APRIL 2016



MS4 Catchment Delineation and Attribute Generation Guidance

Final v 2.0

April 2016

Developed by:



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1 INTRODUCTION

The following MS4 Catchment Delineation and Attribute Generation Guidance helps users (1) delineate MS4 areas into planning level drainage catchments, and 2) generate critical catchment attributes such as land use distribution, imperviousness, soil type, etc. by leveraging existing local and publically available datasets. This guidance assists users with generating a complete and viable spatial dataset and associated products using the minimal amount of effort. However, additional effort and refinement of the spatial datasets will increase the accuracy of the mapping in reflecting the on-the-ground attributes. Refinement can be conducted iteratively, but the degree of refinement should be determined by each municipality based on their available resources and comfort level. Additional technical guidance to help with some of the challenging GIS processes associated with land use mapping is available in Appendix A: Land Use Mapping.

This guidance can be used to create standardized mapped products of an MS4 area that are spatially explicit and useful to anyone involved in urban stormwater management. The maps and attributes generated can be used to meet a number of specific MS4 mapping requirements common in Phase I and Phase II NPDES permits regarding urban watershed or drainage delineations, outfall mapping, high priority land use areas, etc. In addition, the execution of this mapping exercise and the generation of the associated products will provide a spatially appropriate organization to a municipal area that aligns with the physical and chemical linkage between runoff and pollutant generation within the urban landscape, and the structural and non-structural best management practices (BMPs) that are implemented in specific locations within the MS4 to mitigate the stormwater impacts to the local receiving water body.

In particular, the attributes and mapped products generated by following this guidance will be directly usable as inputs into two 2NDNATURE monitoring and modeling tools: the Best Management Practices Rapid Assessment Methodology (BMP RAM)¹ and the stormwater Tool to Estimate Load Reductions². BMP RAM (www.bmpram.com) is a comprehensive and repeatable structural asset management tool for municipalities to inventory, assess the effectiveness and determine maintenance intervals of structural BMPs regularly and cost-effectively. TELR (www.swtelr.com) is an urban hydrology and pollutant loading model that quantifies the cumulative pollutant load reductions to receiving waters as a result of structural and non-structural BMP implementation on an urban catchment scale. The urban catchments delineated as a result of following this guidance document are on the same spatial organizational scale used by TELR and BMP RAM to inform resource expenditure priorities and report the water quality benefits of stormwater program actions.

¹ 2NDNATURE LLC 2016. Best Management Practices Rapid Assessment Methodology (BMP RAM) Technical Document v3. April 2016.

² 2NDNATURE LLC 2016. Tool to Estimate Load Reduction (TELR) Technical Document v1. April 2016.

1.1 Mapping Process

The general process to completing MS4 catchment mapping is outlined below, and each step is detailed in subsequent sections of this report.

- I. MS4 Catchment Delineation
 - a. Data sources for important mapping layers
 - b. Key concepts for catchment delineation, including outfalls, catchments, etc.
 - c. Delineate and refine catchments in an iterative process
 - d. Catchment connectivity to the receiving water
 - e. Field mapping to verify and improve mapping products
 - f. Initial catchment attributes
- II. Attributes
 - a. Catchment attributes, including catchment % impervious, slope, catchment length, precipitation zone and soil type
 - b. Land use attributes, including defining and assigning parcel and road land use area, creating a comprehensive land use layer, and summarizing by catchment

1.2 Intended Audience

This guidance is intended for municipalities to complete the mapping internally. However, completing these tasks requires the municipality to have a GIS department and supporting staff. Some of the GIS processes are technical and will require a moderate to advanced level of GIS expertise. If available GIS resources are limited or assistance with completing these tasks is desired, please contact 2NDNATURE to discuss support options. Users of this guidance and/or stormwater managers are encouraged to contact 2NDNATURE with any questions regarding this guidance or in regards to any 2NDNATURE supported stormwater tool mentioned in this document.

2 MS4 CATCHMENT DELINEATION

There are many reasons a municipality can benefit from delineating an MS4 area into a network of urban catchments:

- Catchments maps provide a spatial understanding of the general stormwater routing units within the MS4.
- Catchments can be used as hydrologic planning units, ideally grouping together areas with similar land uses and allowing for effective planning to control sources of pollutants.
- The finalized catchments can be used to generate and summarize important attributes that can serve as inputs to other stormwater management or urban hydrology or pollutant loading models, including TELR and BMP RAM.

Figure 2-1 outlines the process to delineate an MS4 area into discrete drainage catchments. The final reporting formats are presented in Section 4: Final MS4 & Catchment Attributes.

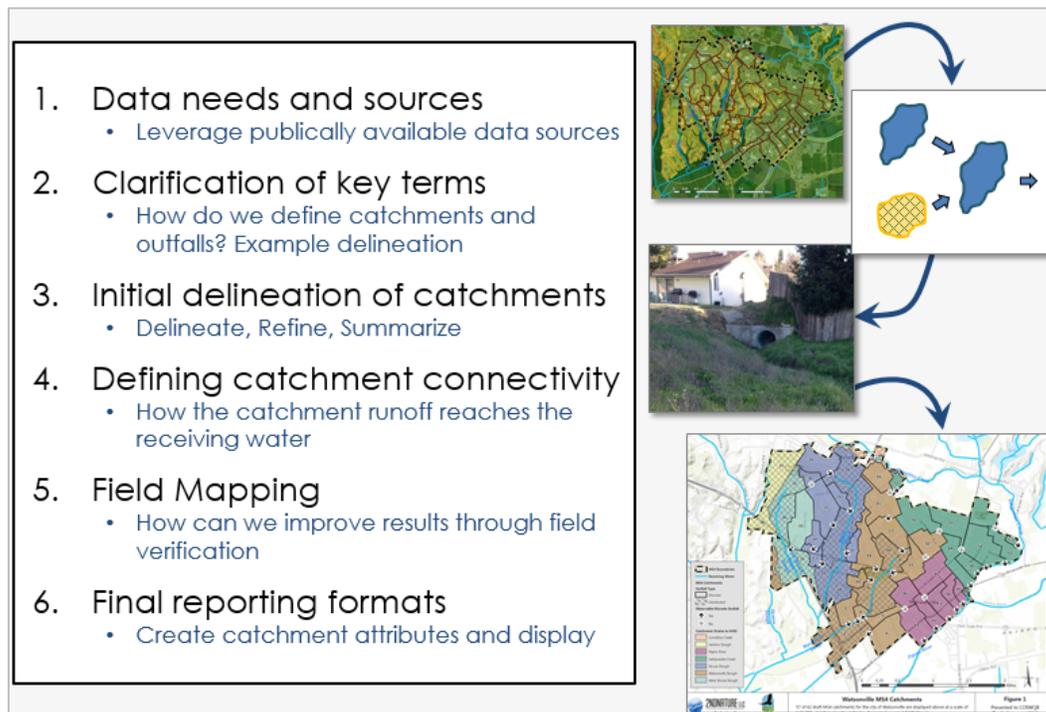


Figure 2-1 MS4 Catchment Delineation Process Overview

2.1 Data Sources

This approach leverages a wide array of publically available data and then integrates local datasets that are available to each specific MS4 to complete these mapping tasks. It is expected that the quality and completeness of local stormwater infrastructure, land use and other datasets will vary greatly across municipalities. However, the approach outlined herein encourages mapping with the available data first. Results can be used to identify where the priority data gaps exist, rather than municipalities expending additional mapping resources prior to completing the Mapping Catchment Delineation and Attribute Generation Guidance.

2.1.1 PUBLICALLY AVAILABLE DATA

Each of the datasets presented below and shown in Figure 2-2 are available for free download from the *National Map Viewer* website (<http://viewer.nationalmap.gov/viewer/>).

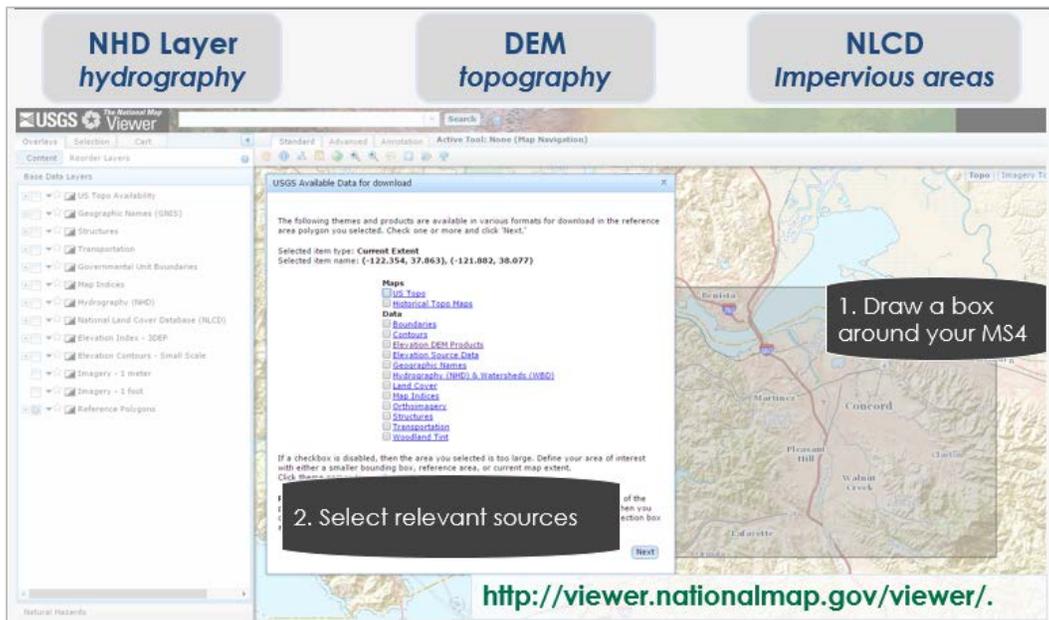


Figure 2-2 National Map Viewer

2.1.1.1 RECEIVING WATERS

The National Hydrography Dataset (NHD) is the recommended layer to define the receiving waters within the MS4. This is a dataset from the USGS that depicts the rivers, streams, coastlines and lakes for the entire country.

All of the catchments and outfalls for each MS4 area must be mapped in relation to the receiving waters to which they drain, but the permit language rarely explicitly defines which waters qualify as “receiving waters”. Representatives from the Central Coast Regional Water Quality Control Board (Region 3) have verified that the USGS NHD layer is an acceptable definition of receiving waters in most instances. Given the NHD dataset’s extent and prominence, we expect that use of the NHD layer is a suitable definition of receiving waters for most municipalities, but this assumption should be verified with the respective MS4 NPDES RWQCB representative.

Figure 2-3 summarizes how to select the correct area and download using the *National Map Viewer* website.

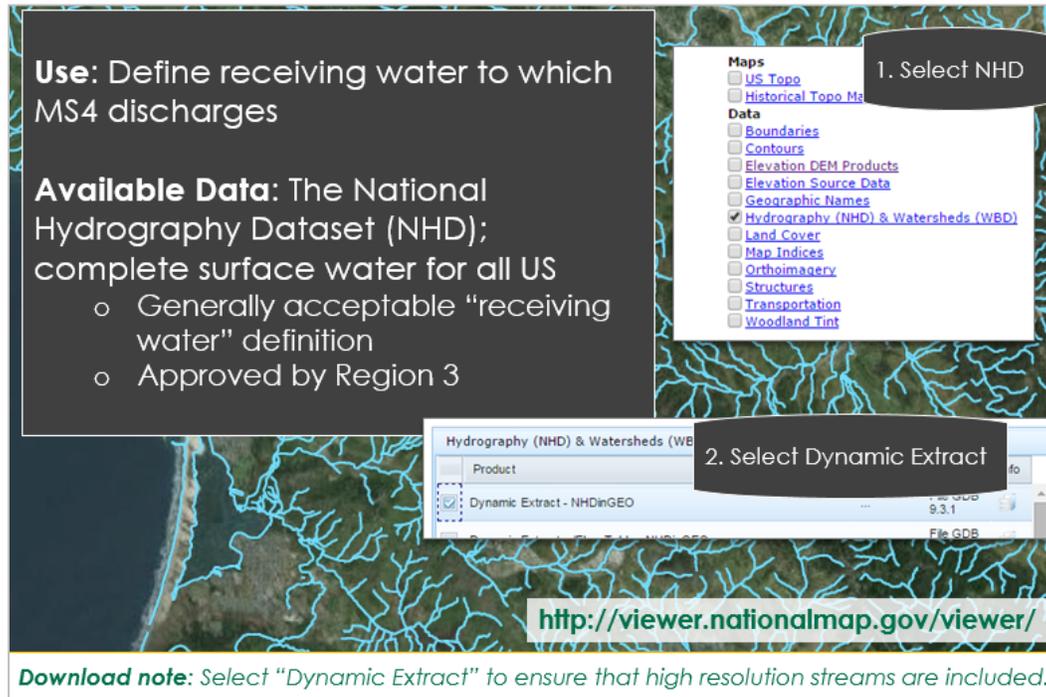


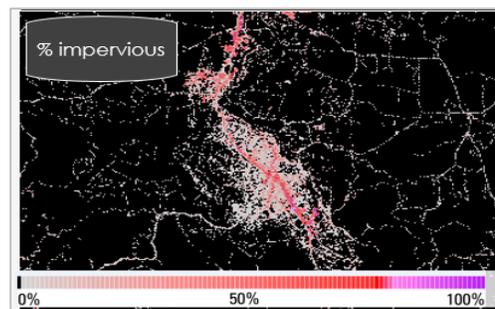
Figure 2-3 Receiving water data

2.1.1.2 MS4 TOPOGRAPHY

Topography and high-resolution stream drainages are used as the first pass for defining unique catchments in the MS4. A high resolution DEM (digital elevation model) or similar layer showing elevation and topography can be used (via tools and processes available in ArcGIS) to create high-resolution streams, elevation contours, and to calculate catchment slope. If current and quality local spatial data layers showing topography and contours are available, the use of those may be preferred. If not, we recommend downloading a ~3 meter resolution DEM, or the next highest resolution elevation layer that is available for the region of interest, from the *National Map Viewer*.

2.1.1.3 LAND COVER DISTRIBUTION

Land cover distribution, particularly the areas of impervious cover, is critical to stormwater routing and pollutant loading patterns. The National Land Cover Database offers both generalized land cover and specific % impervious surface grids. We recommend the 2011 NLCD % Impervious Surface dataset to generate important attributes for each of catchments. NLCD data is available at 30 m resolution for the entire country via the *National Map Viewer*. (Note: While it's always good to have generalized land cover as a reference, such as that available through NLCD, later in this guidance we illustrate how to use Assessors Parcels layers to identify specific and detailed land use for each catchment).



2.1.2 LOCALLY AVAILABLE STORMWATER MAPPING DATA

The best available stormwater infrastructure mapping data for the MS4 should be used. The approach in this guidance works for municipalities with varying levels of stormwater data. However, the accuracy of the map products will reflect the accuracy of the underlying data. Most municipalities are likely to possess some stormwater mapping data, however the accuracy, extent and quality of available stormwater data will vary considerably across agencies. Figure 2-4 provides an example. The combination of topography and stormwater infrastructure will inform how to refine catchment boundaries based on the actual patterns of stormwater routing. Larger municipalities are likely to have developed a stormwater network in GIS, but this might not be the case for counties or more rural municipalities. Most counties have dedicated GIS professionals who are likely aware of the best available stormwater datasets. They may also have additional layers, such as CalTrans stormwater, that can be used to further inform mapping efforts.

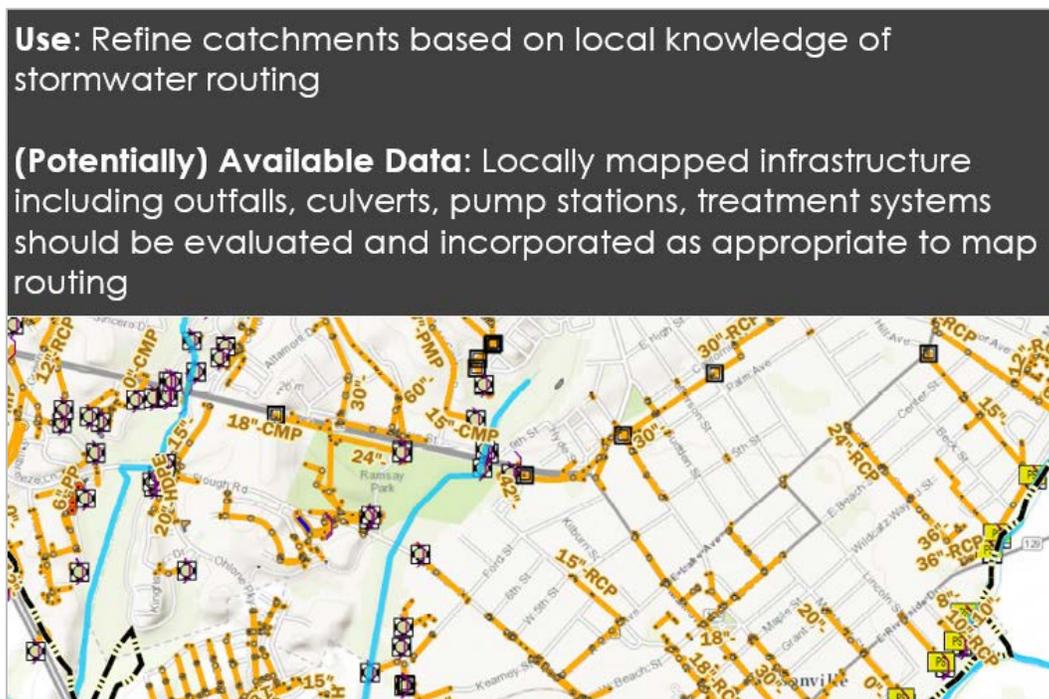


Figure 2-4 Local Stormwater Data

2.2 Key Concepts for Catchment Delineation

Key concepts and terms are defined prior to initiating the catchment delineation process.

- **Urban Catchment:** A contiguous planning unit that represents the hydrologic routing of urban lands within the MS4. Catchments are defined by topography, stormwater infrastructure, and outfalls. We recommend that catchments be delineated with a target size of no more than 100 acres. This is consistent with the sizing that other stormwater management tools and existing stormwater models such as SWMM³ recommend as the maximum area for a catchment. They can have either discrete or distributed outfalls, and for stormwater routing and management purposes, each catchment takes on the characteristics of its outfall.
- **Outfalls:** Locations where stormwater is routed either into another catchment, or into the receiving water.
- **Discrete Outfall:** Where all of the stormwater runoff from a catchment drains to a specific location and is transported to a receiving water or another catchment. A discrete outfall can be specifically mapped and identified. In Figure 2-5, each of the blue catchments have single discrete outfalls.
- **Distributed Outfall:** Where there are multiple locations where stormwater runoff generated within a catchment is transported toward or into a receiving water or another catchment. This can either be via a multitude of small, individual drainage pathways, or via a diffuse, unplumbed catchment boundary. In Figure 2-5, there are many paths that water can take from the yellow catchments to either another catchment or the receiving water.

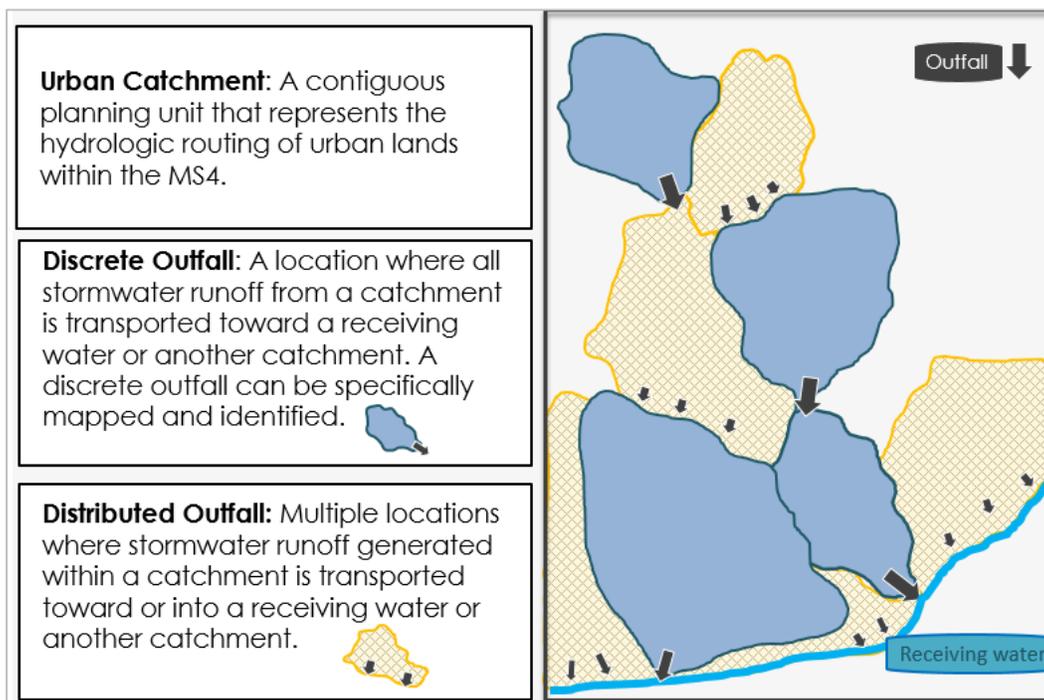


Figure 2-5 Catchments with discrete and distributed outfalls explained.

³ <https://www.epa.gov/water-research/storm-water-management-model-swmm>

2.2.1 DISCRETE VS. DISTRIBUTED OUTFALLS

Urban stormwater catchments have either discrete or distributed outfalls. Each catchment will drain to either another catchment, the receiving water, or out of the MS4 boundary. Discrete outfalls are defined as outfalls where all water generated within a catchment exits the catchment via a single outfall (Figure 2-6 left). A catchment drained by a discrete outfall is known as a discrete catchment.

The target size for urban stormwater catchment delineation is approximately 100 acres. The schematic on the right of Figure 2-6 shows a typical situation where many outfalls with relatively small drainage areas border the receiving water. Delineating discrete catchments for each of these outfalls would result in many small catchments less than 100 ac, each too small for realistic individual management. Instead, we recommend lumping adjacent small catchments into a single catchment where possible. A catchment with multiple outfalls such as this is defined as a catchment with a distributed outfall, or more simply, a distributed catchment. When lumping adjacent small catchments, similar land uses and other commonalities should be taken into consideration. Creating catchments with distributed outfalls reduces the data management burden for the MS4 stormwater personnel, while preserving the hydrologic routing integrity within the MS4. Catchments with diffuse boundaries where no obvious outfall exists can also be defined as distributed. These are often found directly adjacent to the receiving water.

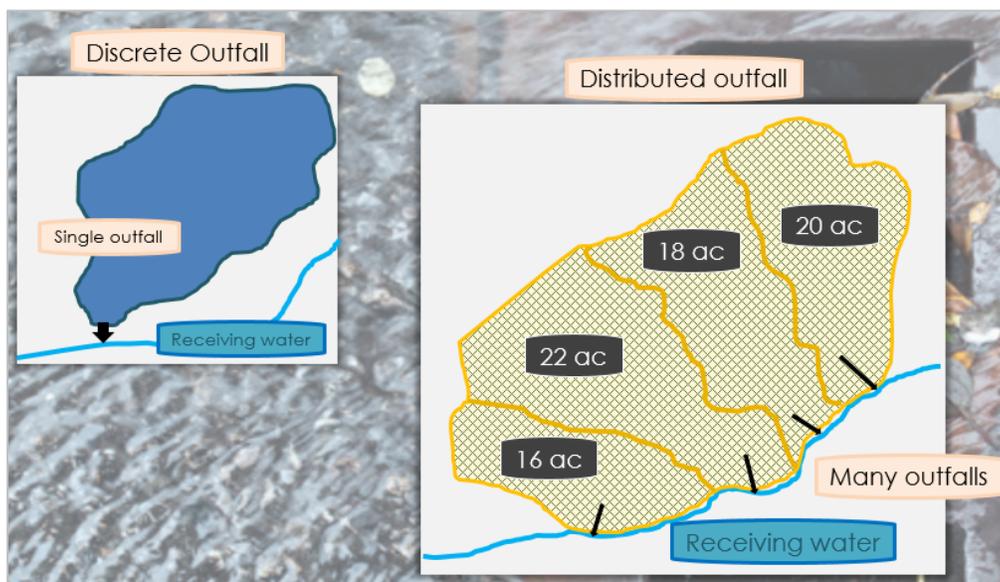


Figure 2-6 Outfall schematics

2.2.2 CATCHMENT TO CATCHMENT ROUTING

A number of considerations should drive the catchment delineation toward meeting the 100-acre size requirement. Stormwater infrastructure, land use, impervious surface density, or other factors might lead to catchments being significantly smaller, or slightly larger than the 100 acre target. The catchment sizing is a recommendation, not a requirement, and the most important principle is that the resulting catchment makes sense as a cohesive management unit to the respective municipality.

As catchment boundaries are drawn to approximate 100 acres, most catchments will drain into another catchment prior to discharging to the receiving water. All connection combinations of catchments with discrete or distributed outfalls are possible (Figure 2-7).

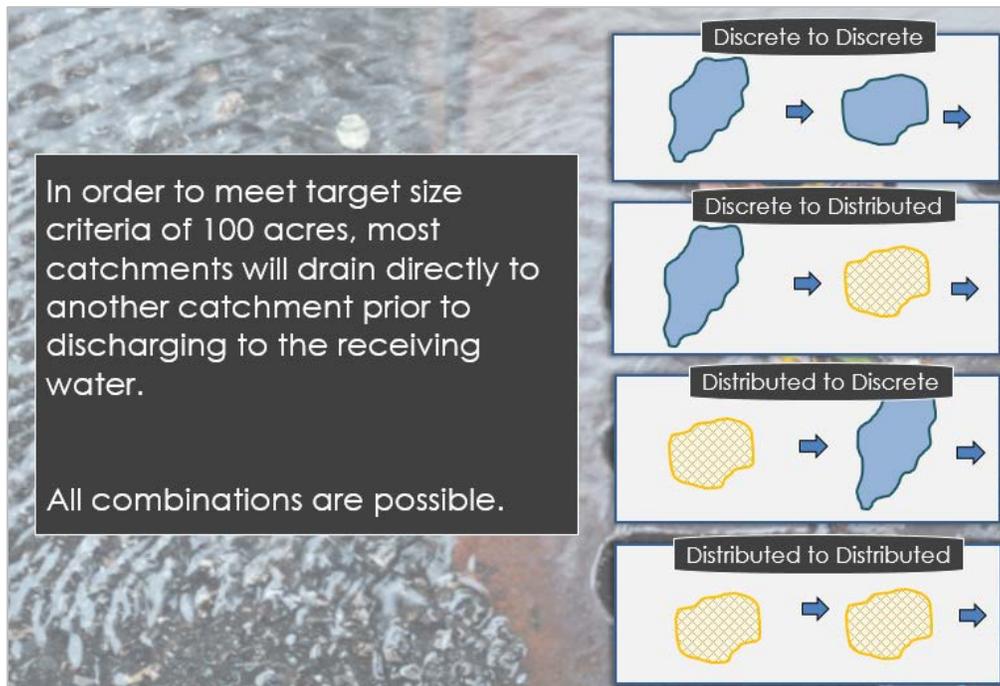


Figure 2-7 Catchment to catchment routing schematics

When delineating catchments and determining flow routing, do not violate basic hydrologic concepts. Multiple catchments can converge and flow into a single catchment, however the opposite is not true (Figure 2-8). Catchments should not be delineated so that the water would flow into two separate catchments. A catchment will either discharge into another catchment, flow to the receiving water, or flow out of the MS4 boundary.

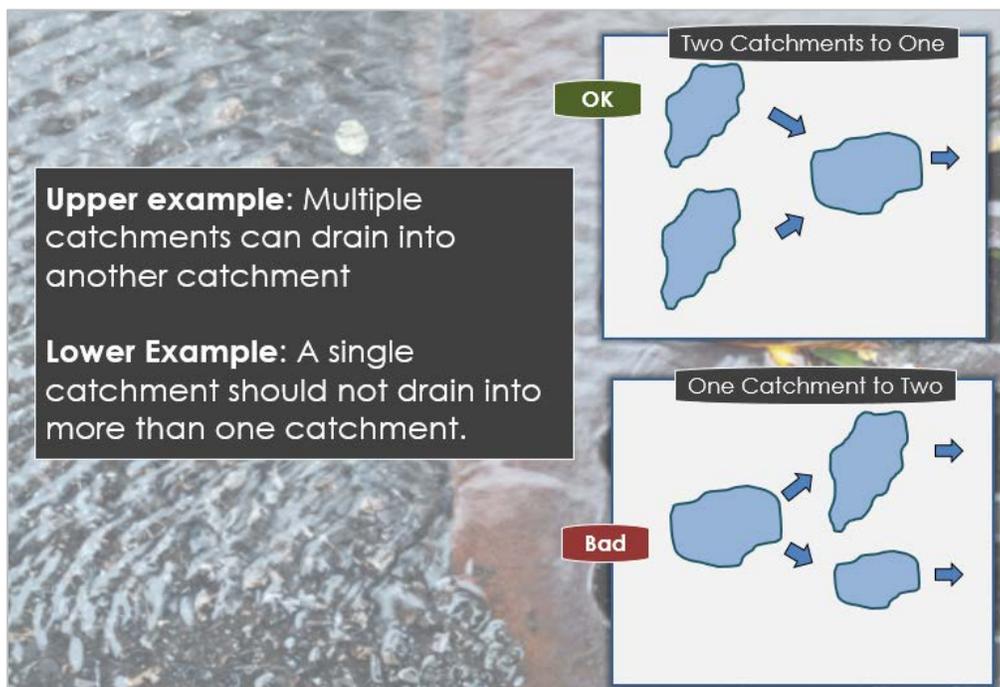


Figure 2-8 Catchment to catchment routing principles

2.2.3 SPLITTING LARGE DRAINAGES INTO SMALLER CATCHMENTS

In many cases, the initial delineation of catchments will result in a catchment that well exceeds the 100 acre target and should be split into smaller catchments, yet there is not an obvious strategy for doing so. In this case it is acceptable to find some point based on stormwater infrastructure (shown in orange in Figure 2-9) and topography where a boundary can be drawn at a certain drainage constriction point. At this location, preferably close to a manhole or some recognizable stormwater infrastructure location, we suggest adding what we call an “inaccessible outfall” to the map. This “inaccessible outfall” is displayed as a grey arrow and can be used to re-draw the catchment boundaries and define the point at which the upper newly-defined catchment flows into the lower. The two catchments now meet the size criteria.

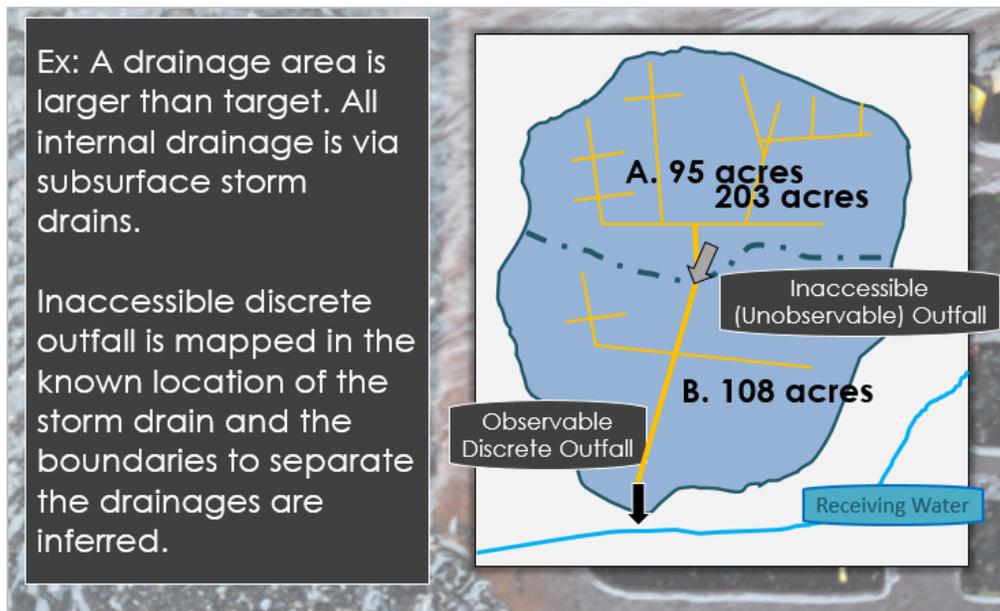


Figure 2-9 Splitting catchments: inaccessible outfall

Another common scenario is when there is a large catchment with no clear “constriction point” between the upper and lower portion (Figure 2-10). Information such as land use distribution, slope, or impervious surface density can be used to split the catchment. In the example below, the upper area in the catchment (A) may be largely undeveloped rural upland, while the lower area (B) may be highly developed and more urban. We can therefore split the catchment in two to reflect this. Since there are many connection points from A to B, the outfall for catchment A will be considered “distributed”.

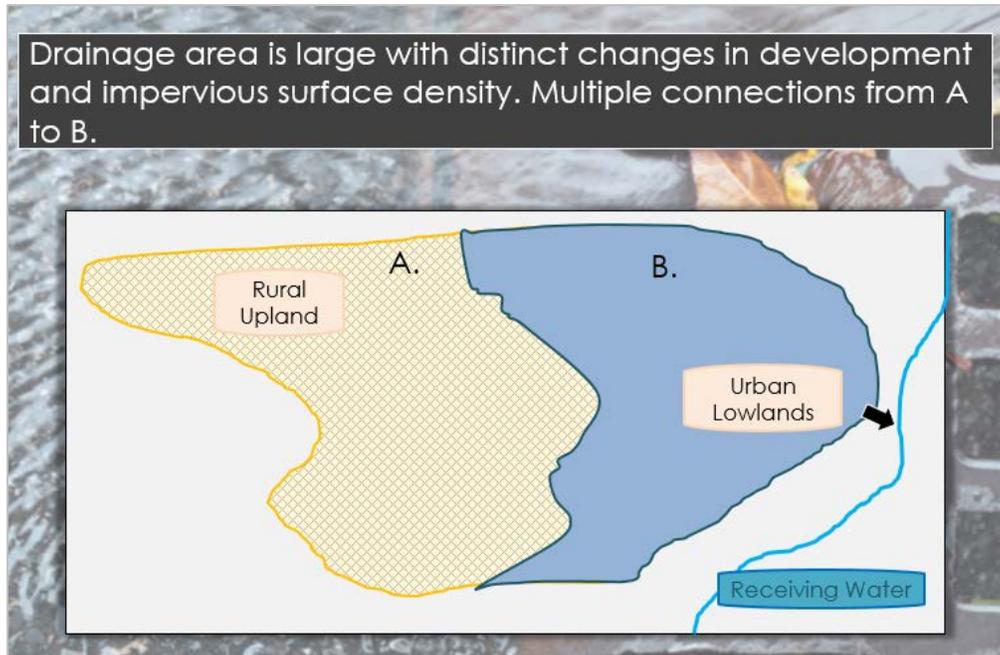
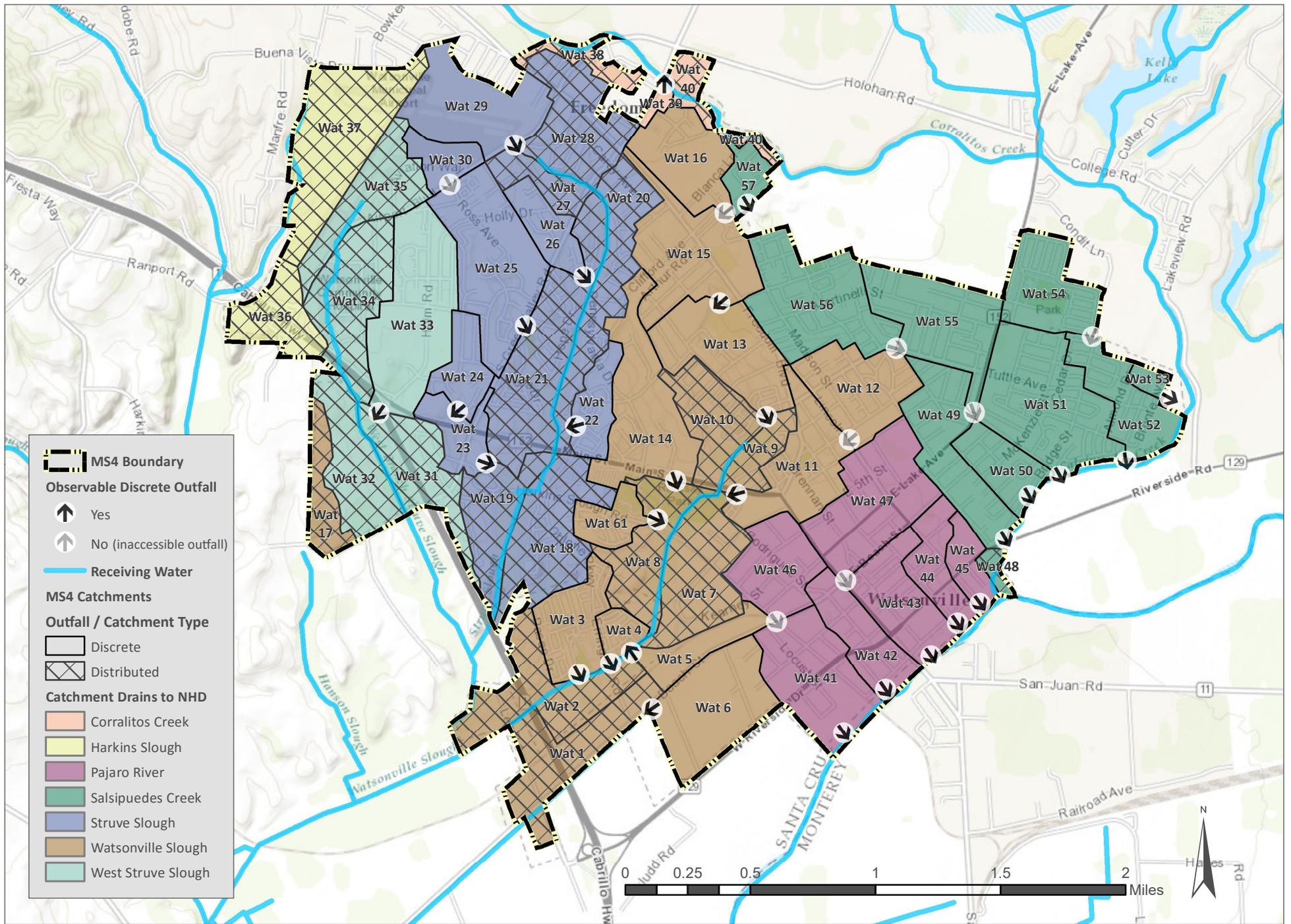


Figure 2-10 Splitting catchments: changes in land use and impervious surface density

Figure 2-11 on the next page illustrates how these concepts are illustrated in the final mapped product. Exploring the legend, each catchment is defined by either a discrete or a distributed outfall, which are indicated on the map as solid vs. hatch-marked catchments, respectively. Every catchment flows either into another catchment, the receiving water, or out of the MS4, but never into two separate catchments. The outfall of each catchment is clearly defined and it is indicated whether it is an observable discrete outfall or a non-observable “inaccessible” outfall.



Final MS4 map product example illustrating catchment IDs, catchment boundaries, receiving waters, outfall type and direction, and the catchments grouped by the NHD receiving water to which they drain

Figure 2-11

2.3 Delineating and Refining Catchments

Using the datasets and concepts discussed above, the process for delineating catchments is outlined below. These steps must be completed using GIS software such as ArcGIS.

2.3.1 DELINEATE MAJOR BASINS

The first step is to delineate the major basins within the MS4 area. The major basins are the areas within the MS4 that drain to different NHD receiving waters. Using the receiving waters layer and other drainage information, such as high resolution streams and contours, which can both be created easily in GIS from a DEM grid, split the MS4 area into simple, common sense major basins showing the complete areas draining to different receiving waters (Figure 2-12). For some MS4s, there may be only one receiving water. In those cases, use topography where possible to subdivide the area based on any major drainage divides.

After this initial delineation, evaluate if any major basins are near the target of 100 acres. If so, use these as the catchment boundaries. However, in most cases the basins will need to be further divided into smaller catchments.

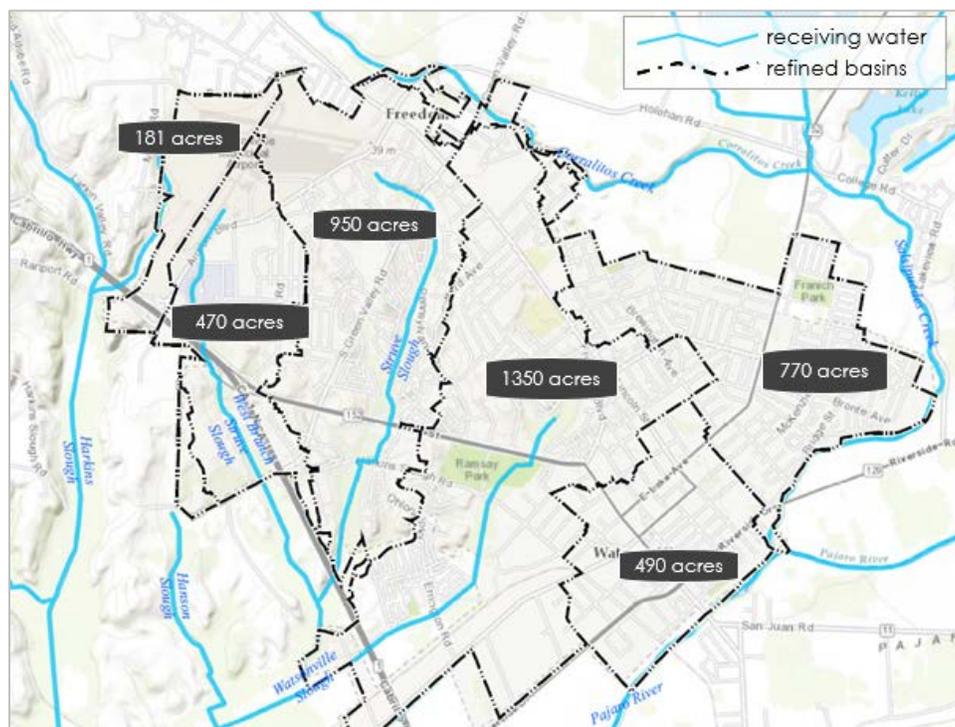


Figure 2-12 Major basin delineation

2.3.2 CATCHMENT DELINEATION

Delineating and refining catchments is an iterative process. Begin by displaying the high-resolution drainage data, such as the stormwater infrastructure and streams layers. Using this data along with topography and artificial barriers such as roads, split each of these major basins into smaller areas based on expected flow paths. As much as possible, delineate draft catchments on the order of 100

acres each. A couple revisions using this higher resolution data may be needed to pare down each catchment to an acceptable size.

Throughout this iterative process, some tips to keep in mind include:

- Choose one major basin at a time, starting at the top (uphill) and working towards the terminus at the receiving water.
- Begin by targeting areas that are obviously discrete outfalls. After delineating the discrete outfalls, the distributed catchments should naturally fall in line and become apparent.
- If topography is not clearly the driver of a catchment, consider artificial conduits and barriers to water flow such as stormwater infrastructure or roadways.

To refine catchment boundaries, turn all data layers on and zoom to the upper portion of a major basin (Figure 2-13). Starting at the uphill side of the area of interest, assess the catchment's boundaries based on the stormwater infrastructure and topography. Some outfalls will be clearly marked on the stormwater data layer, and may indicate clean definitions between one catchment and another. It is common practice for stormwater systems to route stormwater according to topography, however sometimes there are features that will cross topographically-derived boundaries and require catchment refinement. After the outfall has been identified and the boundary is refined, the catchment is given a unique ID and the area is calculated.

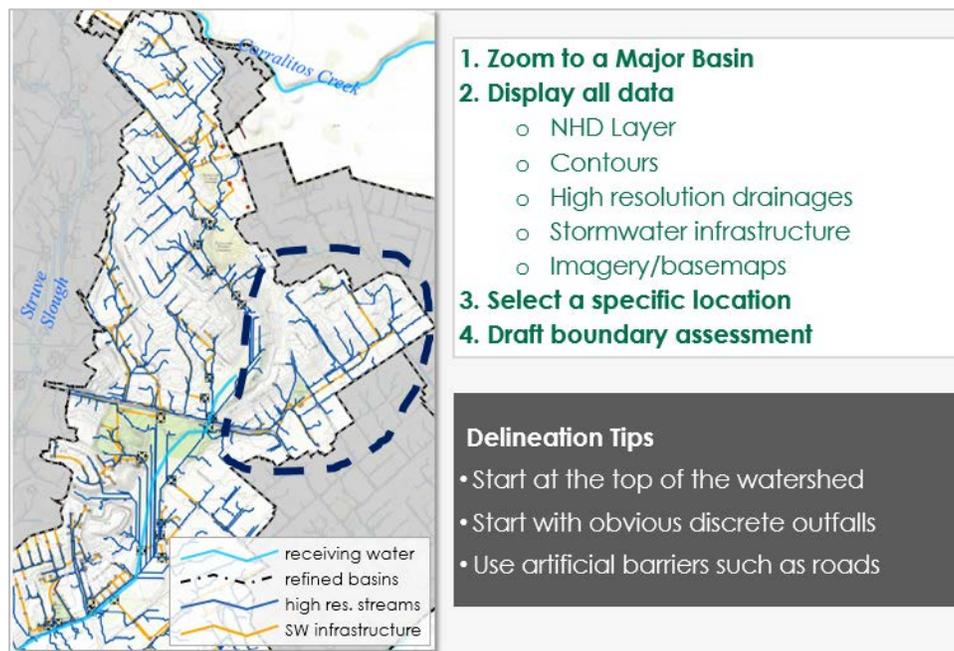


Figure 2-13 Catchment delineation process

Figures 2-14 to 2-16 provide a step by step example of delineating and refining catchment boundaries.

In Figure 2-14 the high resolution drainages mimic the stormwater infrastructure. The upper boundaries of the catchment have already been defined in the major basin delineation. Now the final boundaries and outfall can be assessed. Based on the data, the outfall is located at the black arrow. Since all the water is routed to a single location, this is a discrete outfall. The catchment boundary is checked against

the streams, topography and stormwater infrastructure data and is refined where needed. However, the catchment is still too large so we will now look into some other options to split it further.

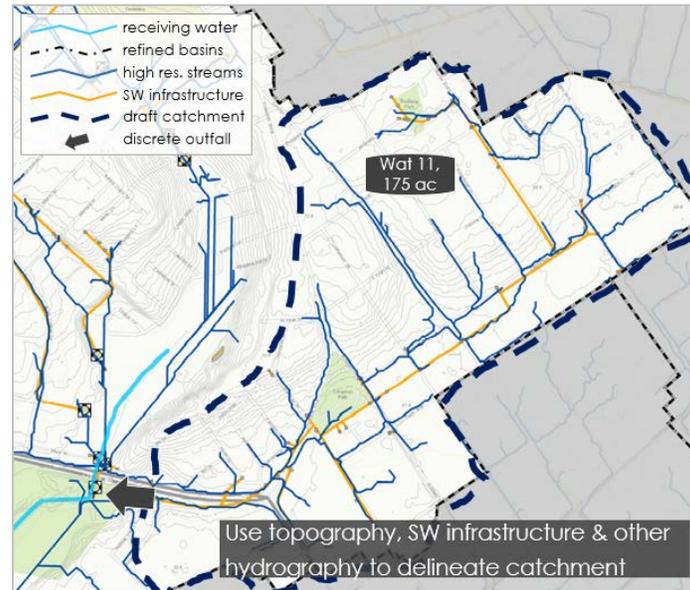


Figure 2-14 Catchment delineation example: Large catchment

To refine boundaries and split large catchments into smaller areas, first look for obvious differences in land use or management. This can also be a good practice when trying to define catchment boundaries that are not hydrologically obvious. For example, as discussed above in Sec. 2.2.3, there are many cases where a rural upland will abut an urban lowland. Depending on the context these can be separated into distinct catchments based on land use, with the resulting rural upland being a distributed catchment and the urbanized lower catchment being a discrete one. In Figure 2-15, the land use is similar throughout the catchment so another approach is needed. (Note: “land use” in this case can be assessed simply using aerial imagery available in ArcGIS, Google Earth or other; we discuss the identification of specific land uses pertinent to calculating catchment stormwater loads later in this guidance).



Figure 2-15 Catchment delineation example: Split by land use

In Sec. 2.2.3, “inaccessible outfalls” were discussed as a means to artificially split one large catchment into two smaller ones based on the principle of finding a common constriction point in the stormwater infrastructure or natural hydrology. The outfall is “inaccessible” since it is somewhat arbitrary and would likely be underground if visited in the field. In the current example, this method is used to split this one large catchment into two smaller ones.

- First, use the stormwater and drainage data to look for a place where the flow constricts. Take note that the blue drainage lines were created in GIS using a topography layer and are estimates of where water might flow. They do not account for storm drains, so in this example the blue lines near the inaccessible outfall most likely are all routed through the stormwater system (orange) and not along the streets as they might appear.
- Once the inaccessible outfall has been identified, use topography to draw in a boundary between the newly-defined upper and lower catchments.
- At this point, two reasonably sized catchments have been delineated based on known stormwater conveyance infrastructure. If the boundaries were still uncertain, consider verifying the boundaries in the field or consulting fellow stormwater staff that may be more familiar with the stormwater routing and infrastructure.

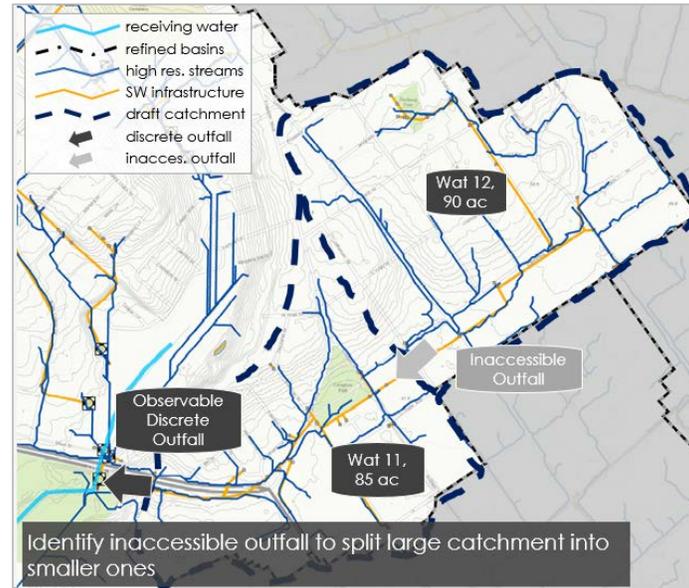


Figure 2-16 Catchment delineation example: Split with inaccessible outfall

After iterating between stormwater data, drainage data, topography, land use, and best professional judgment, a comprehensive draft catchment map should exist, particularly for upper basin areas. Some catchments will have discrete outfalls and some will be distributed. To improve communication, clearly designate each on the catchment map.

The next step is to investigate the areas directly adjacent to the receiving water. In these areas, there are typically many distinct outfalls to the receiving water as well as areas that would drain into the receiving water through overland flow. Typically these catchments will be defined as distributed (Figure 2-17).

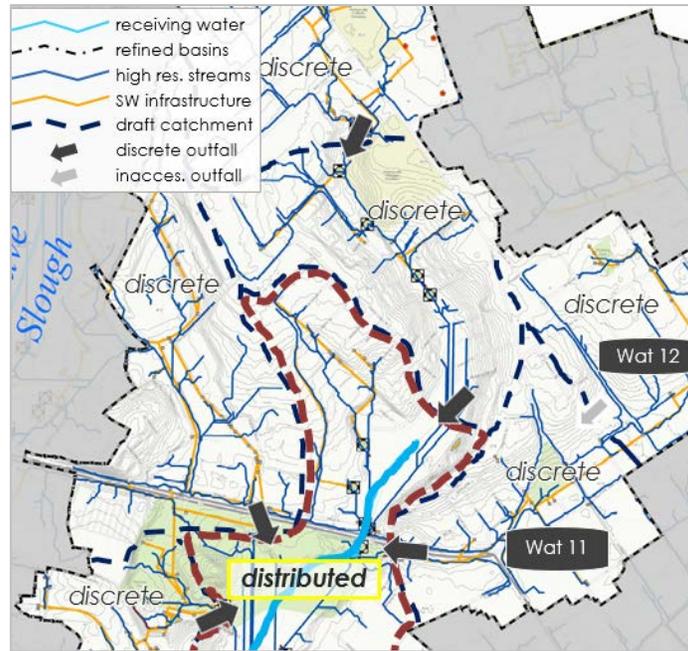


Figure 2-17 Distributed catchments near receiving waters

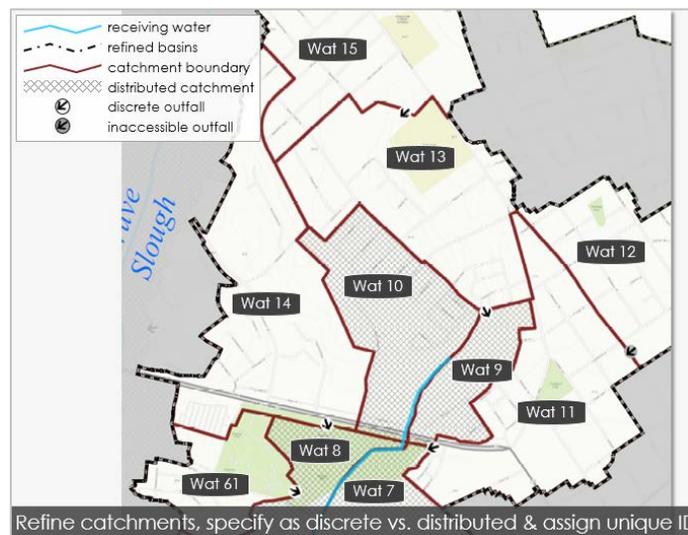


Figure 2-18 Outfall type and catchment ID

The same refinement process is applied throughout the MS4 to delineate all the catchments within the major basins, and all the major basins within the MS4. For each catchment, the outfall type (discrete or distributed) is defined and the catchment is assigned a unique catchment ID (Figure 2-18). The next section describes other critical catchment attributes that are required.

2.4 Catchment Connectivity

Catchment connectivity is used as a relative definition of the fraction of stormwater that exits the catchment and reaches the receiving water. Connectivity is important in order to scale the potential risk of the stormwater volumes or pollutants generated within a catchment by the fraction of these pollutants that will actually enter the receiving waters. Catchment connectivity is determined by evaluating catchment spatial relationships and flow path characteristics to one another and to the receiving water (Figure 2-19).

What we ultimately want to know is: what is the fraction of stormwater that exists the catchment that makes it to the receiving water?

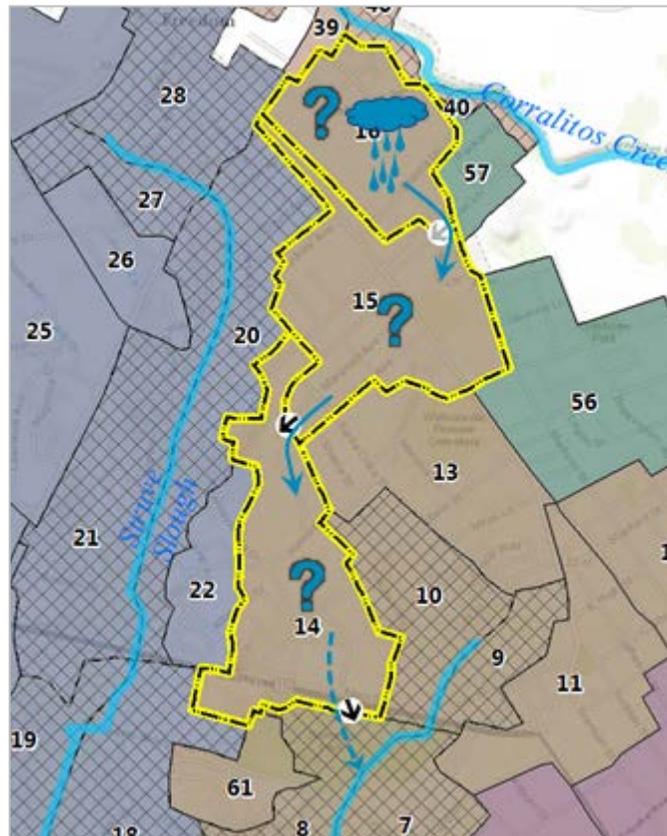


Figure 2-19 Catchment connectivity schematic

General rules define how catchment connectivity is determined by catchment routing. Ultimately, the connectivity of every catchment must be determined, but this determination process starts at catchments in closest proximity to the receiving waters. Then, **all upstream catchments inherit the connectivity of the furthest downstream discrete outfall.**

Catchment connectivity is specifically evaluated for:

- ❖ Any catchment directly adjacent to a receiving water (Figure 2-20, catchments X and M).
- ❖ The furthest downstream discrete catchment (Figure 2-20, catchments Y and M).
- ❖ Any catchment adjacent to the MS4 boundary that drains to a receiving water outside of the MS4, whether that catchment is discrete or distributed (Figure 2-21, catchments Y and N).

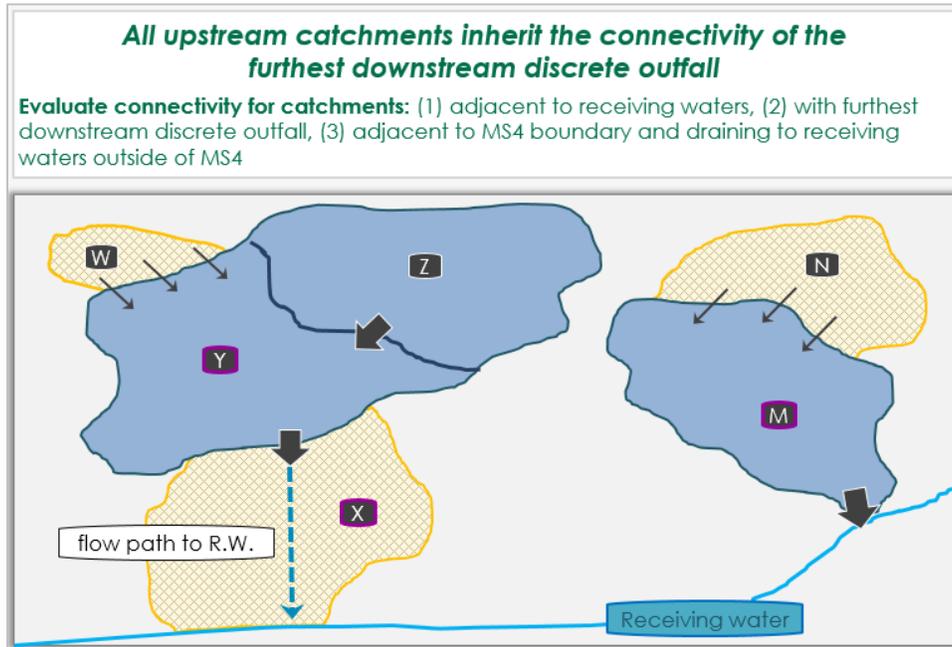


Figure 2-20 Upstream catchment connectivity: example 1

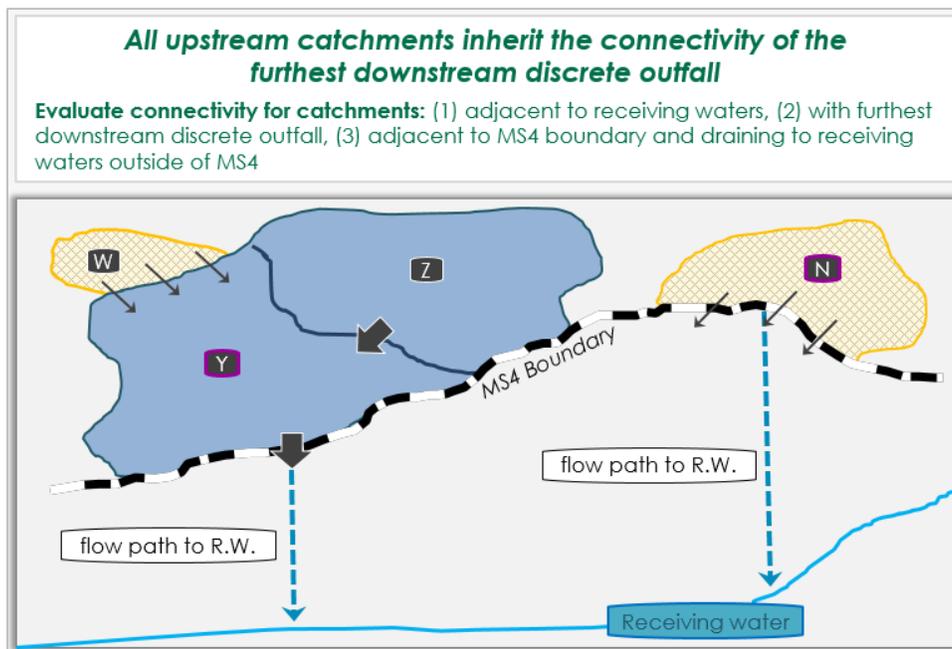


Figure 2-21 Upstream catchment connectivity: example 2

2.4.1 CATCHMENT CONNECTIVITY OF OUTFALL

Catchment connectivity is on a relative scale that provides general bounds for assessing catchment connectivity based on probable storm runoff volume. The scale is based on the catchment outfall characteristics and distance from the receiving water, and the approach is developed to be science-based, yet simple enough, such that two users applying the guidance will determine a similar relative connectivity for the same catchment.

To illustrate the relative scale, examples of the two end members—always connected and never connected—are described. In Figure 2-22, the culvert discharges runoff towards the receiving water (which in this photo happens to be a dry channel). Because the outfall is so close to the receiving water, it is assumed that any and all flow that occurs at the outfall would discharge into the receiving water, and therefore all of the catchments above this outfall would be 100% connected.

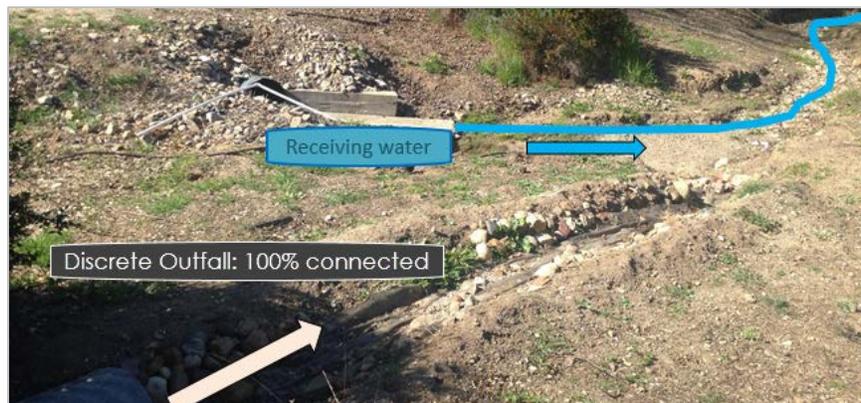


Figure 2-22 100% hydrologically connected

In Figure 2-23, the discrete outfall discharges into a wide meadow far from the receiving water. This outfall is clearly not hydrologically connected to the receiving waters. Any runoff from this outfall would spread out and infiltrate into the field. None of the runoff water would make it directly to the receiving water, and all of the catchments above this outfall would be 0% connected.



Figure 2-23 0% hydrologically connected

The actual amount of discharge reaching receiving waters is dependent on many factors including: distance, discharge volume, antecedent conditions, slope, channel morphology, permeability, and more. Figure 2-24 below provides guidance for defining the connectivity from an outfall. Besides always and never, the remaining three categories for relative connectivity are: rare, common, and average. “Rare” implies that only really large storms would generate enough runoff to reach the receiving water. In other words, only storms in the 75th percentile or larger would be big enough for this to happen. The class “common” suggests that most storms, except for the really small ones, would be big enough to produce runoff that would reach the receiving water. “Average” falls somewhere in between common and rare.

Relative Connectivity	Value	Description
Always	100%	Any and all flow that occurs at the outfall discharges into the receiving water
Never	0%	Flow that occurs at the outfall never reaches the receiving water
Rare	25%	Only 75 th percentile peak daily runoff (e.g. <i>only really big storms</i>) reaches the receiving water
Common	75%	All flows except the smaller 25 th percentile peak daily runoff (e.g. <i>all but the really small storm events</i>) reach the receiving waters
Average	50%	All flows that exceed the average peak daily runoff (e.g. <i>all storms average and above</i>) reach the receiving waters

Figure 2-24

Figure 2-25 provides a decision matrix to evaluate the connectivity for all outfalls that are adjacent to receiving waters, adjacent to and draining out of the MS4 boundary, and all of the furthest downstream discrete outfalls. Generally, follow this approach:

- ❖ If the outfall is distributed and the catchment is directly adjacent to the receiving water, then the catchment is 100% connected.
- ❖ If the outfall is discrete or if it is a distributed catchment not adjacent to the receiving water, look for any evidence of a flowpath. A flowpath is the course that water takes from one point to another. An example would be a small swale, channel (impervious or pervious), or pipe. Another indicator of a flowpath might be slight erosion or deposition of sediment indicating past water movement.
- ❖ If there is **no** evidence of a flowpath to the receiving water, the channel is likely not connected to the receiving water (0% connectivity).
- ❖ If the flowpath is an impervious concrete channel or a pipe, where minimal loss through infiltration is expected, the channel is likely always connected to the receiving water (100% connectivity).
- ❖ If the flowpath is pervious, use Figure 2-26 to estimate the catchment connectivity.

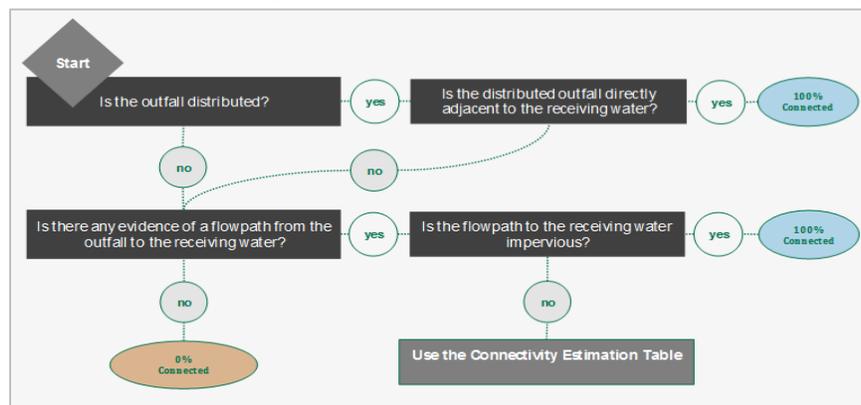


Figure 2-25 Catchment connectivity decision matrix

Connectivity Estimation Table		
Length of pervious flow path connecting outfall to receiving waters	Impervious acreage of full drainage area	
	< 60 acres	> 60 acres
	% connected	
< 500 ft	75%	100%
500-1000 ft	50%	75%
1000 – 2000 ft	25%	50%
>2000ft	0%	25%

Figure 2-26 Catchment connectivity estimation table

The values in Figure 2-26 are based on the hypothesis that some stormwater volume will be lost through infiltration in a pervious flow path. The longer the flow path, the greater the surface area and potential for loss. Also, the greater the area of impervious surface draining to that flow path, the greater the volume of generated runoff and thus the higher the likelihood of water reaching the receiving water. Putting these concepts together, connectivity is evaluated by estimating the length of pervious flow path connecting the outfall to the receiving water and the total impervious acreage of the full drainage area. "Full drainage area" includes all catchments draining to the outfall, not solely the immediately upstream catchment (Figure 2-27).

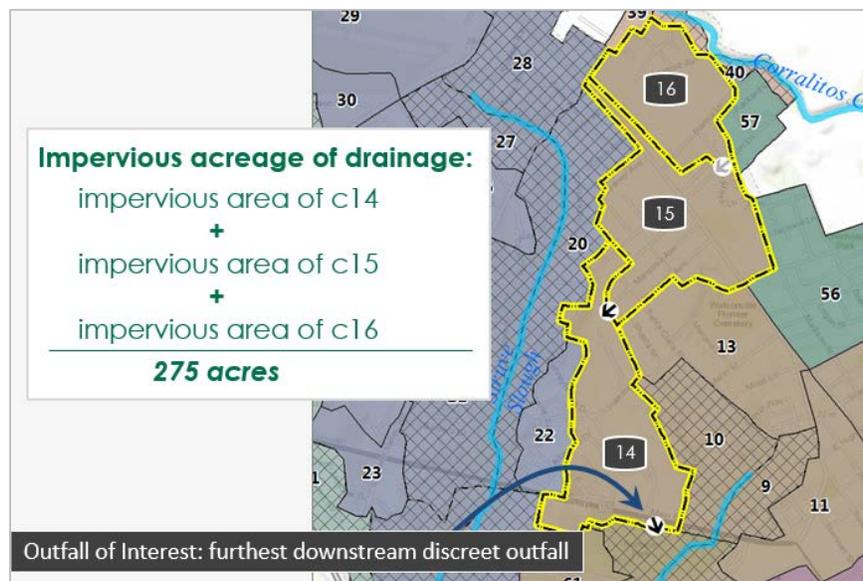


Figure 2-27 Full drainage area calculation

The 60 acre distinction between large and small catchments is based on the runoff response of a ½ inch daily rainstorm. The ½ inch daily storm represents the upper end of an average event on the Central Coast of CA, which is where this guidance was originally tested. This type of event on 60 acres would generate approximately 1 cubic foot per second of water, which is easy to visualize and represents a reasonable cutoff between large and small catchments.

2.5 Field Mapping

To this point, the guidance has assumed that in most cases the catchment boundaries, outfall locations, and catchment connectivity can be determined in the office using existing GIS data and detailed aerial imagery. This is especially convenient when catchments and outfalls are located on private property or are in a remote location that is difficult to access. However, there will be times when some field verification will be necessary.

2.5.1 OPTIMIZING TIME IN FIELD

Field mapping can potentially be a resource-intensive process, especially if the intent is to verify every outfall and boundary. The following are some tips for being efficient with field resources (Figure 2-28):

- Prioritize important areas. Focus verification efforts on areas with dense concentrations of urban area that drain directly to the receiving water, as these areas have the most potential impact on stormwater management.
- Identify the delineated areas that remained uncertain following the first assessment in the office. Note these uncertain catchments during initial delineation, along with the general reason for the uncertainty (e.g., insufficiently mapped stormwater infrastructure, unclear outfall location) and use field verification to resolve these issues.
- Have a clear plan. Bring all the tools and data into the field that will be necessary to complete the mapping. Develop specific questions and datasheets ready before leaving the office.

Prioritize Areas

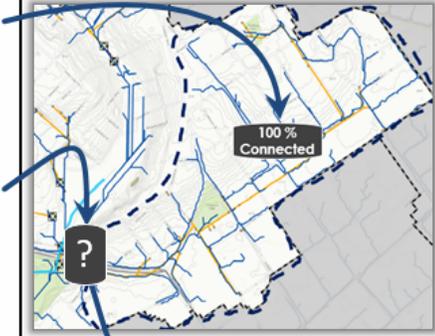
- Start assessments with highly impervious areas with clear connection to receiving water

Identify Areas of Uncertainty

- Do we understand routing through catchment? What is the outfall type?

Have a Plan: Priority Questions

- What specific example data will answer question?
- Create datasheet to answer question
- Create field map with necessary information



Office Data				Field Verification		Office Adjustment	
Catch ID	Drains To	Out type	Outfall ID	Catchment Connectivity	Outfall Channel Type	Catchment Connectivity	
SC 22	NHD	Discr ete	SC22a	75%	Concrete	100%	Update attribute table

Figure 2-28 Tips for field mapping

2.5.2 EXAMPLE FIELD QUESTIONS

Figures 2-29 to 2-30 provide example field questions, approaches, and field datasheets for common questions.

What is the catchment connectivity?							
<ul style="list-style-type: none"> Reason for question: Using aerial imagery, cannot tell if catchment outfall structure is a concrete or pervious flow path What to do in field: <ul style="list-style-type: none"> Locate outfall & walk length to receiving water Take photographs Update field datasheet 							
Office Data				Field Verification		Office Adjustment	
Catch ID	Drains To	Out Type	Outfall ID	Catchment Connectivity	Outfall Channel Type	Catchment Connectivity	Catchment Connectivity
SC 22	NHD	Discrete	SC22a	75%	Concrete	100%	Update attribute table

Figure 2-29 Field mapping: catchment connectivity

Is the catchment outfall in the correct location?									
<ul style="list-style-type: none"> Reason for question: Aerial imagery inconsistent with available stormwater infrastructure mapping. What to do in field: <ul style="list-style-type: none"> Locate and GPS actual outfall location Take photographs Update field datasheet 									
Office Data				Field Verification				Office Adjustments?	
Catch ID	Drains To	Out Type	Outfall ID	Correct Location ?	Outfall Size	Photo ?	GPS?	Outfall	Boundaries
Wat 22	NHD	Discrete	Wat22	N	36"	Y	Y	Move	Adjust

Figure 2-30 Field mapping: outfall location

Other issues that may arise during field mapping:

- Unmapped flow paths: Aerial imagery near an outfall may indicate a potential flow path to the receiving water that is not included in the stormwater data. Visit the site to determine if there is any evidence that water is routed through the flowpath. In the office, adjust catchment boundaries and connectivity values as appropriate.
- Unmapped outfalls: GPS the location of the outfall and complete the outfall datasheet. In the office, use the data to refine catchment boundaries and attributes and to reassign catchment IDs in a logical order as necessary.

2.6 Initial Catchment & Outfall Attributes

Following any adjustments from the field mapping, review the catchment boundaries with any invested parties to further edit the catchment boundaries and outfall locations. The final catchments are assigned a unique ID, their outfalls are clearly displayed, and the attributes in Figure 2-31 are assigned.

MS4 Catchments			
Attribute Name	Field Type	Example	Description
MS4Area	Text	Watsonville	The extent of the MS4 area
CDP	Text	Watsonville	Census Designated Place
catchID	Text	Wat 47	First three letters of CDP followed by a unique number
acres	Double	95	Catchment area (acres)
outType	Text	Discrete	Outfall type, discrete or distributed
outVerify	Integer	2015	Year that outfall was field verified, leave blank if site was never visited
drainsToRW	Text	Harkins Slough	Indicates NHD receiving water that catchment eventually drains to. If NHD receiving water is not named, indicate "unnamed stream"
drainsToCatch	Text	Wat43	Downstream, terminal catchment by which catchment hydrologic connectivity is defined for subject last catchment.
connect	Double	25%	Catchment hydrologic connectivity (relative %)

Figure 2-31 Initial catchment and outfall attributes

Create a final map displaying the MS4 catchments, their defining outfalls and their routing. The goal of the map is to clearly communicate key catchment and outfall attributes as well as stormwater routing at a large scale to someone unfamiliar with area. The example map (see Figure 2-11) was created using our recommended display format, which has been approved by the Region 3 RWQCB.

The final map product includes:

- The MS4 boundary and receiving waters clearly displayed
- Catchments labeled by ID, with clear indication of discrete or distributed outfalls
- Catchments are colored to indicate to which major NHD stream it drains. In MS4 areas with only one receiving water, or in areas where all the streams are unnamed, this may not make sense.
- Outfalls labeled with an arrow to indicate the routing of water through the MS4 area. The outfall type is clearly indicated to show whether or not it is an observable discrete outfall.
- The MS4 area is displayed at a reasonable scale where each catchment can be clearly seen. This may required more than one map.

Another Central Coast RWQCB Phase II permit Section E9 deliverable is the "Outfall to Receiving Water Map Display". The mapping formats and data needed for this map are similar to what is shown in Figure 2-32. For this map deliverable, every stormwater outfall within 500 feet of the receiving water is required to be displayed and includes all known outfalls discharging to receiving waters. This will include all outfalls in distributed catchments, as well as those in discrete catchments. The reporting formats for this map (Figure 2-32) and its attributes (Figure 2-33 and Figure 2-34) have also been approved by the region 3 RWQCB.

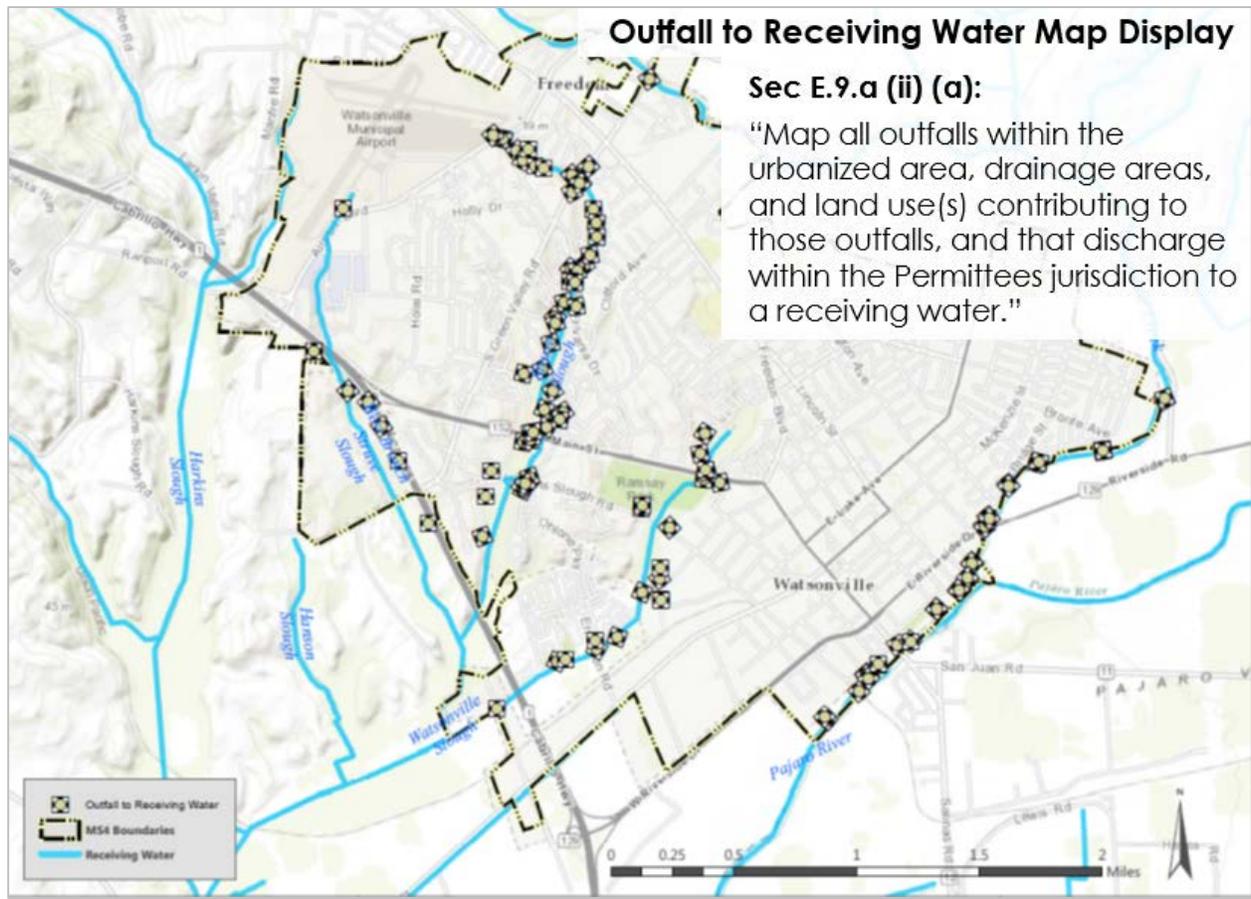


Figure 2-32 Catchment outfall map

Outfalls			
Attribute Name	Field Type	Example	Description
catchID	Text	Wat 47	catchID of the catchment that the outfall drains
outID	Text	Wat 47a	Catchment Id followed by a letter
outMATCH	Text	DP23	Outfall ID used by the municipality if already mapped. Leave blank if it has not been mapped.
Lat	Double	36.910409	Longitude measured in Decimal Degrees
Long	Double	-121.75444	Latitude measured in Decimal Degrees
obsOut	Text	Yes	Observable discrete outfall. Either "Yes" or "No"
rot_Azi	Integer	84	Azimuth angle used to display outfall direction for map
out_Size	Text	36"	Outfall Size, indicate measurement in inches or feet

Figure 2-33 Catchment outfall attribute table

catchID	outID	outMATCH	Lat	Long	obsOut	rot_Azi	out_Size
Wat 47	Wat 47a	e34672342	36.919	-121.746	No	25	
Wat 48	Wat 48a	e34672343	36.927	-121.771	Yes	138	32
Tem 27	Tem 28a	sl-478-2	35.550	-120.706	Yes	254	18
Sba 62	Sba 63a		34.429	-119.699	Yes	48	48

Figure 2-34 Example of a catchment outfall attribute table

3 ATTRIBUTES

Section 2 clarified key terms, described the process to delineate catchments, and provided results of clearly defined and mapped urban stormwater catchments. Section 3 describes how to calculate the land use attributes for each catchment that are critical inputs to calculating stormwater pollutant loading and runoff potential. Figure 3-1 shows the attributes already generated for each catchment from the guidance in Section 2 (highlighted in blue), and it shows the attributes (highlighted in green) which will be discussed in the following pages.

MS4 Catchments			
Attribute Name	Field Type	Example	Description
MS4Area	Text	Watsonville	The extent of the MS4 area
CDP	Text	Watsonville	Census Designated Place
catchID	Text	Wat 47	First three letters of CDP followed by a unique number
acres	Double	95	Catchment area (acres)
outType	Text	Discrete	Outfall type, discrete or distributed
outVerify	Integer	2015	Year that outfall was field verified (leave blank if site was never visited)
drainsToRW	Text	Harkins Slough	Indicates NHD receiving water that catchment eventually drains to. If NHD receiving water is not named, indicate "unnamed stream"
drainsToCatch	Text	Wat43	Downstream, terminal catchment by which catchment hydrologic connectivity is defined for subject last catchment.
connect	Double	25%	Catchment hydrologic connectivity (relative %)
imp	Double	62%	% impervious surface within catchment based on Land Cover layer
SFR	Double	14.49	Single family residential land use within catchment (acres)
MFR	Double	38.00	Multi-family residential land use within catchment (acres)
IND	Double	0.00	Industrial land use within catchment (acres)
COMM	Double	9.50	Commercial land use within catchment (acres)
CULT	Double	1.90	Cultivated land use within catchment (acres)
OTHER	Double	0.00	Other land use within catchment (acres)
HTR	Double	4.75	High traffic density paved roads within catchment (acres)
MTR	Double	4.75	Moderate traffic density paved roads within catchment (acres)
LTR	Double	5.70	Low traffic density paved roads within catchment (acres)
rdsUL	Double	0	Low traffic density unpaved roads within catchment (acres)
precip	Double	2	Precipitation zone (1, 2, 3, 4, 5)
soil	Text	D	Soil type category (A,B,C,D)
catchL	Integer	2300	Catchment length (ft)
catchS	Double	2%	Catchment average slope (%)

Figure 3-1 MS4 catchment attributes

3.1 Catchment Attributes

The following additional attributes are required TELR inputs, and are likely required inputs to any urban hydrology model. Generating these attributes is simple and will likely prove useful to MS4 stormwater planning in the future.

3.1.1 PERCENT IMPERVIOUS BY CATCHMENT

Percent impervious area is a critical attribute to understanding catchment loading, as impervious areas on the landscape are responsible for the vast majority of stormwater runoff. There are a number of ways to calculate and summarize this value by catchment. The following is a simple approach.

- In GIS, load the MS4 Catchments layer created in Section 2, and the “National Land Cover Database, 2011 % Impervious Surfaces” layer (Figure 3-2).

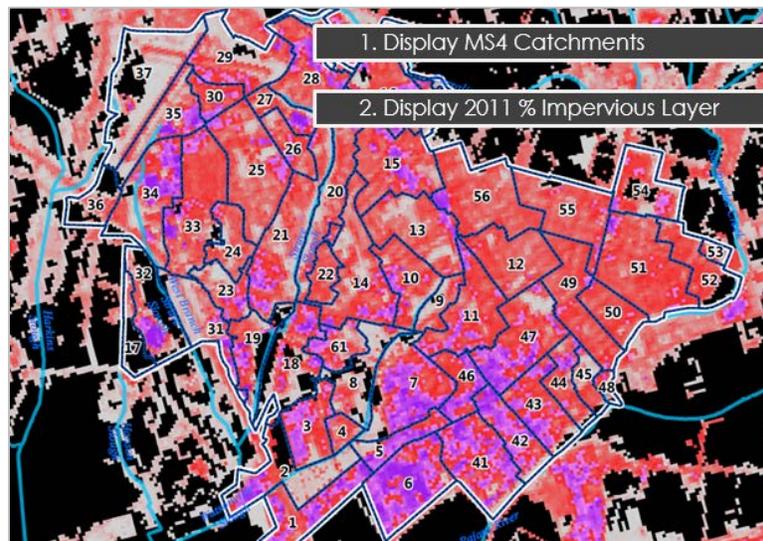


Figure 3-2 MS4 catchments and NLCD impervious surfaces layer

- Open the “Zonal Statistics as Table” tool, which can be found in the spatial analyst toolbox. Run the tool specifying the “MS4 Catchments” as the “feature zone data”, with the “CatchID” field as the “Zone field”, and “% Impervious Surfaces” layer as the “Input value Raster”. Select OK to run the tool (Figure 3-3). A table will be output showing the results.

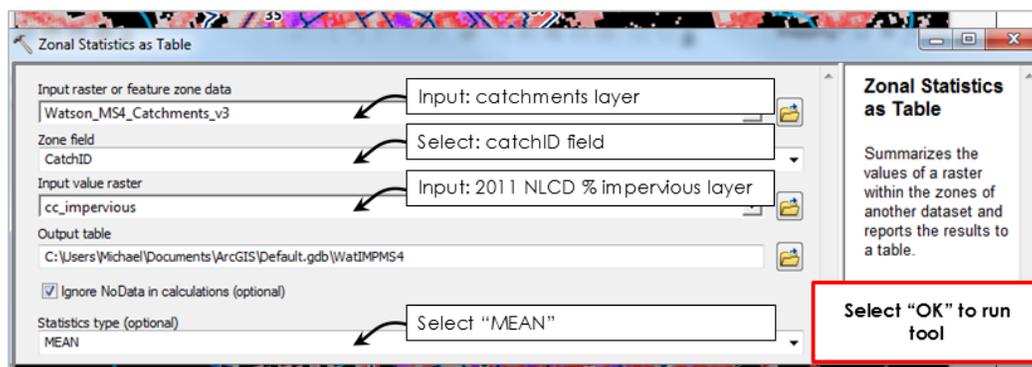


Figure 3-3 Zonal statistics results

- Open the output table. The catchment ID is displayed along with the mean % impervious area value for each catchment.

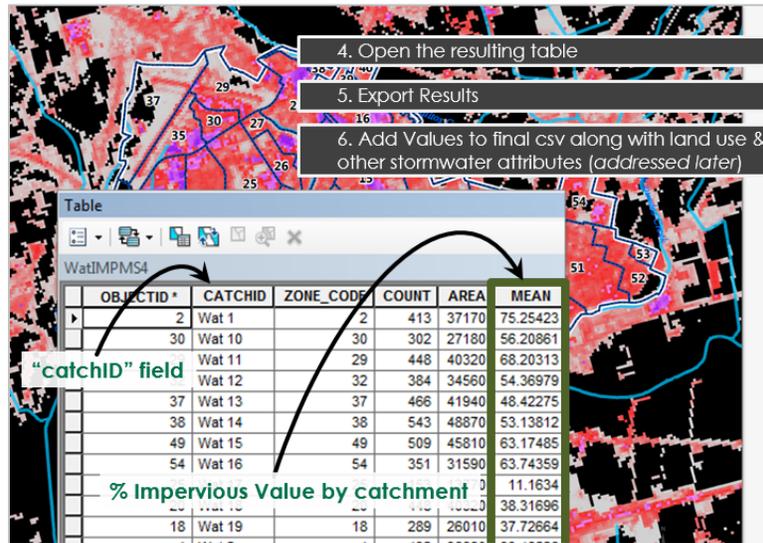


Figure 3-4 Zonal statistics output table

- Export this table as a “dBase” or “csv” file to a location that can accessed later.

3.1.2 CATCHMENT SLOPE

Catchment Slope is used in BMP RAM for catchments that drain to a centralized structural BMP. Many municipalities may already have a layer with % slope. The following provides a simple approach to generate a % slope layer and summarize the data by catchment (Figure 3-5).

- Create an MS4-wide slope layer by using the “Slope” tool and a DEM (Digital Elevation Model) layer. Select the (% rise) option in the tool to express the output as percent slope. If the DEM does not match the coordinate system in the map, a z-factor correction may be necessary.
- Once the slope layer is created, use the “Zonal Statistics as Table” tool to generate the average slope per catchment. The catchments layer will be the “input feature zone” while the slope layer will be the “input value raster”, and the statistic to calculate will be the average.

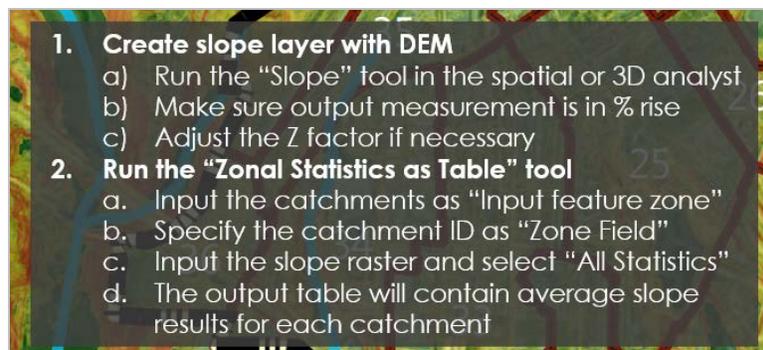


Figure 3-5 Catchment slope calculation

- Export this table as a “dBase” or “csv” file to a location that can later be accessed when we add this attribute, along with the others we discuss here, to each catchment.

3.1.3 CATCHMENT LENGTH

Catchment length is measured as the “primary flowpath” through the catchment. This attribute is also used in BMP RAM for catchments that drain to a centralized structural BMP. The “primary flowpath” is the path that the majority of water would take from the top boundary of the catchment to the bottom boundary. This path can be estimated from the stormwater infrastructure lines and the flow lines and can be measured in feet using the ruler tool in GIS (Figure 3-6).

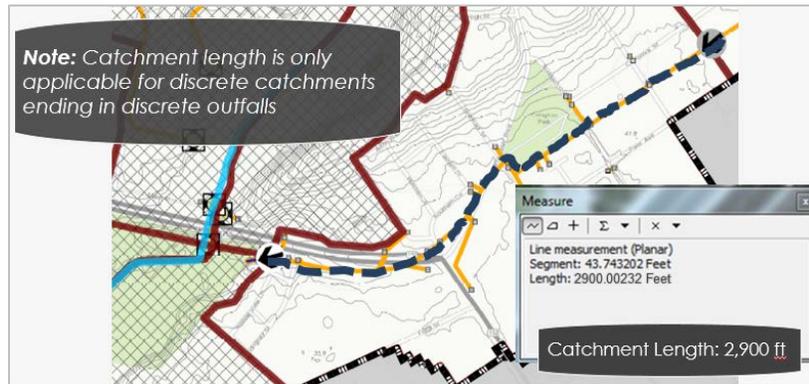


Figure 3-6 Catchment length calculation

Figure 3-7 provides two examples for consideration:

- In example A, the catchment length is measured as the distance from the very top of the catchment to the outfall using topography and stormwater infrastructure.
- In example B, there are multiple flow paths through the catchment - none of which are obviously the primary flowpath. In this case, the average of two flow paths are used to estimate the catchment length.

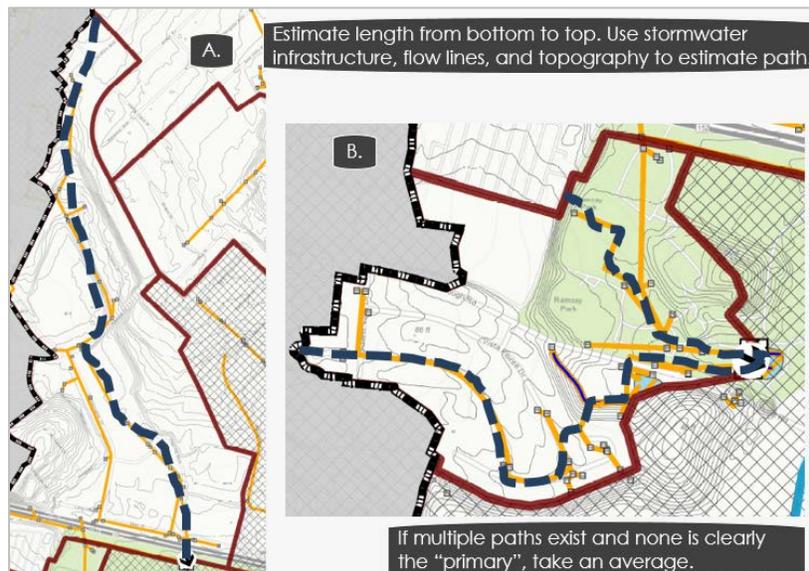


Figure 3-7 Catchment length measurements

The catchment length attribute is manually assessed and should be recorded in a table or another format that can easily be joined to the other catchment attributes.

3.1.4 PRECIPITATION ZONES

Delineating the landscape into precipitation zones provides a consistent, simple, yet scientifically robust dataset to drive the precipitation inputs of 2NDNATURE's urban pollutant loading model (TELR). Using the breadth of available NOAA met stations, decades of data have been pre-processed to reduce and classify these data into regional zones. For the purposes of estimating the load reductions of stormwater programs, the Central Coast region can be reasonably represented by the 5 zones shown in Figure 3-8. 2NDNATURE is in the process of classifying these data for other regions, so please contact us if data outside of the Central Coast is needed. (Central Coast data is available upon request from the 2NDNATURE ftp site).

After downloading the appropriate regional precipitation zone layer, display the data along with the MS4 catchment boundaries. Zoom in to see the MS4 in detail and assign each catchment with the most applicable precipitation zone. If a given catchment is between two categories, select the category representing the largest amount of area. In most instances, a single category will represent the entire MS4 area.

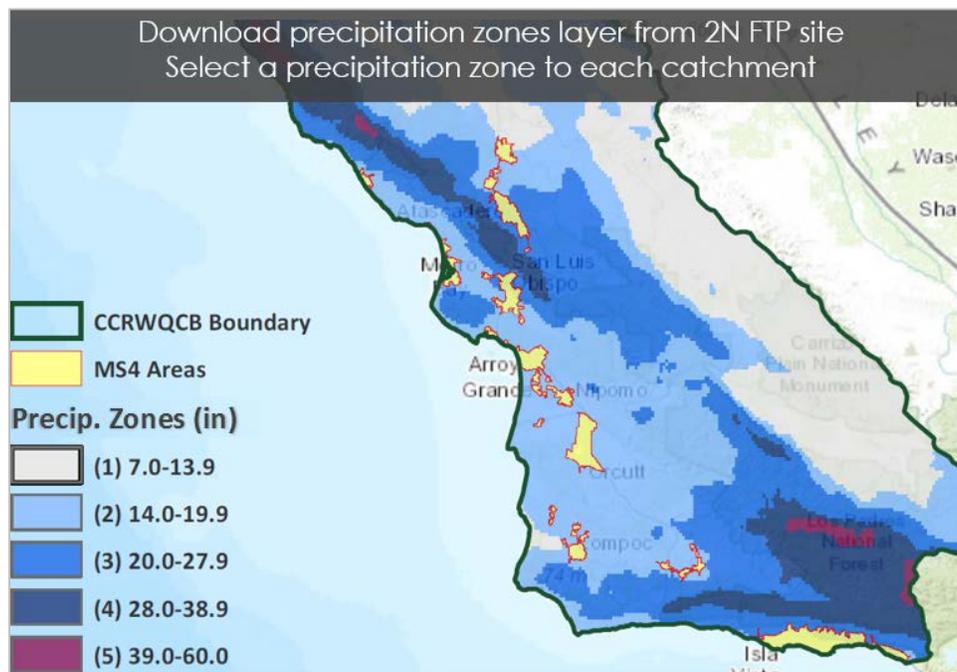


Figure 3-8 Central Coast precipitation zones

3.1.5 SOIL HYDROLOGIC GROUP

The NRCS-defined Soil Hydrologic Group (HSG) is a critical input to stormwater models and has large implications on runoff volumes. Soils groups are defined for each MS4 catchment. While GIS layers with HSG defined can be downloaded from a number of sources, the recommended source is ESRI's SSURGO Downloader 2014 (Figure 3-9). This will ensure that the soils data is current, and that all users are utilizing the same format.

- *To Download:*
<http://www.arcgis.com/home/item.html?id=4dbfecc52f1442eeb368c435251591e>



Figure 3-9 SSURGO Downloader

The NRCS HSG's are categorized as A, B, C, or D (Figure 3-10). Similar to the precipitation zones, view this data overlaid with the MS4 catchment boundaries and assign a soil group for each catchment. The soils are a key indicator of runoff potential, with A having the lowest and D the highest potential. When there are relatively equal amounts (within 5% of catchment area) of distinct HSG's, select the HSG with the highest runoff potential. In the rare areas where there is an A/D or C/D soil type (different soil HSG when inundated), assume that the soil type is D.

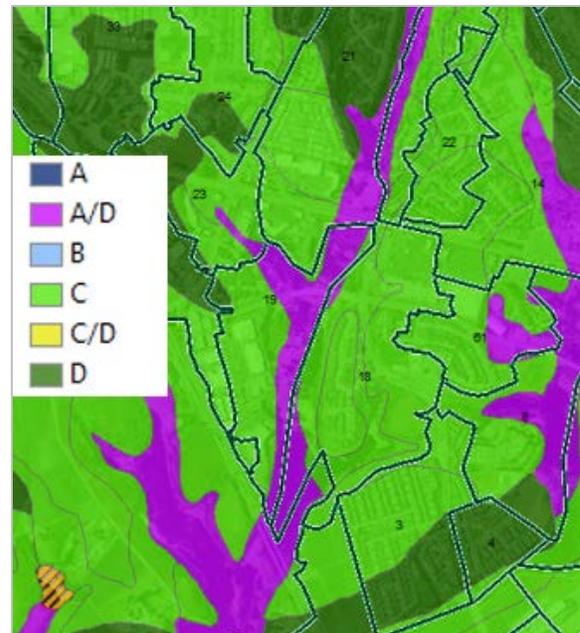


Figure 3-10 NRCS HSG categories

3.2 Land Use Attributes

The process to determine land use by catchment is complex and can be challenging to conduct. The MS4 permit requires that the land uses associated with each catchment are specified, but no details are provided on how to classify land uses nor how they should be reported. The greatest roadblock to this effort is the lack of a consistent, comprehensive land use data source—with adequate detail—that can be used for the entire Central Coast, let alone the entire state of California. Many municipalities may have land use mapping from past efforts, but these products have a wide array of attributes and often do not include road networks. Below, 2NDNATURE provides a standardized approach to determining the land use distribution within each catchment. Extended guidance on how to create a complete land use layer for an MS4 area is available in Appendix A: Land Use Mapping.

3.2.1 LAND USE DEFINITIONS

Table 3-1 defines the land use types approved by the regional board and consistent with TELR model inputs.

LU Type	LU Name	Definition
IND	Industrial	The industrial land use includes a wide variety of land uses including manufacturing, power generation, processing of products and more. Pollutant loads from industrial land uses are expected to be the highest of all land use categories.
COM	Commercial	Areas with structures that sell products or provide commercial services. These includes hospitals, shopping centers (and parking lots), schools, grocery stores and motels. Loading from commercial land uses is expected to be lower than industrial, but higher than residential land uses.
MFR	Multi-family Residential	Any areas with multiple residences including townhouses, apartments, mobile home parks, condos or the like. Loading from MFR land use type is below commercial, but higher than SFR.
SFR	Single Family Residential	Any parcel zoned for no more than a single residence. Loading from SFR is lower than MFR.
CUL	Cultivated	Includes all agricultural lands where crops are grown, but not agricultural facilities and dairies (which would be classified as industrial). The pollutant loading from this land is characterized by management practices on soil (e.g., tilling, irrigation) and application of fertilizer.
OTH	Other/Open Space	All undeveloped areas with minimal structures or paved roads. Includes parks, open space easements and campgrounds. Due to the relatively natural conditions, OTH land uses are expected to have minimal loading contributions.
HTR	High Traffic Roads	Roads and adjacent right of way areas that receive relatively high traffic for a given municipality. Road classification systems often identify Freeways, Onramps, and Major arterial roads as high traffic.
MTR	Medium Traffic Roads	Roads and adjacent right of way areas with medium traffic densities for a given municipality. Classifications that can be considered moderate include lower traffic arterial roads and major collectors.
LTR	Low Traffic Roads	Roads and adjacent right of way areas with relatively low traffic density for a given municipality. Typical road descriptions that fall into this category are local, light duty, alleys, and most other undefined road types.
rdsUL	Low Traffic Unpaved	Roads and adjacent right of way areas that are not paved with any impervious surfaces.

3.2.2 LAND USE CROSSWALK

There are many potential sources for land use data. The most important requirement is that the data must have enough detail in order to decipher the 6 parcel-based land use classes (roads are from a separate data source). Many municipalities may have previously-developed land use layers that can be used for this effort, but the data will need to be classified into the land use classes in Table 3-1.

For the sake of consistency and to be comprehensive, we recommend using the “assessor’s parcel layer”. Every municipality has assessor’s parcels, and within this layer there is usually an “assessor’s use code”—a land use code used for tax purposes. This layer is sufficiently detailed, but can often include hundreds of land use codes that must be re-classified into the 6 land use attribute classes. The parcels will most likely not include any of the four roads classes (HTR, MTR, LTR, rdsUL).

To convert assessor’s parcel use codes into the 6 land use attributes, create a crosswalk.

1. Identify the assessors use codes layer in GIS and export the attribute table data to Excel
2. List the assessors use codes in Excel in one column
3. Reclassify each parcel code into one of the land use attributes

When unclear about how to reclassify a parcel, consult the definitions and use best professional judgement. Extended guidance on how to create a crosswalk and example reclassifications is available in Appendix A.

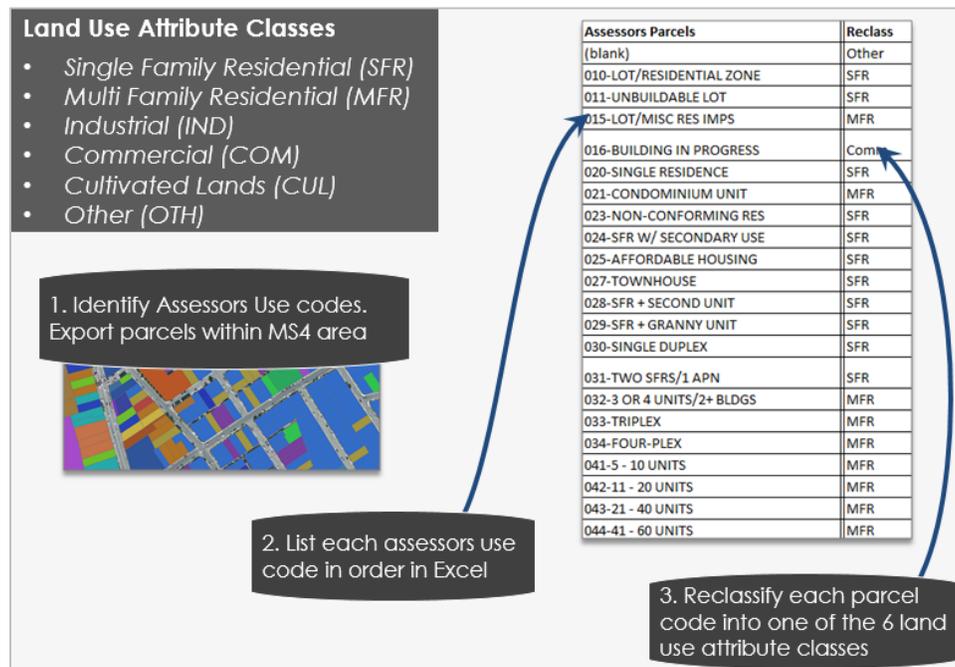


Figure 3-11 Land use crosswalk

3.2.3 PARCEL LAND USE QAQC

The crosswalk is used to translate all assessors' parcels into the 6 land use categories. The following will provide quick steps to bring the crosswalk into GIS and to QAQC it. Extended guidance and examples are available in Appendix A.

1. Save the crosswalk as a .csv file and add it into GIS.
2. In the Assessor's parcel layer use the "Joins and Relates" tab to match the assessor's use codes in the layer and crosswalk. *See Appendix A for details*
3. Export the joined layer and title it "Parcel_LU"
4. Display the "Reclass" field from the crosswalk
5. QAQC LU classification
 - o Check on LU Codes that were potentially classified incorrectly
 - o Look over entire layer to make sure that land uses assigned to parcels meet LU definitions
 - o Change Land Use Codes or parcels if incorrectly classified

Following QAQC, the final parcel layer will look similar to Figure 3-12. Note that roads and right of way areas are not included yet.



Figure 3-12 Parcel layer map showing data gaps for roads and right of way

3.2.4 ROADS LAYER

Roads are not usually included in the parcel layer (see Figure 3-12) and thus the total acreage of land uses from the assessor's parcel layer will not match the full acreage of the catchments or MS4. Bring the roads data into GIS from another source and generate a roads land use layer with the following information:

1. Acreage of roads within each catchment (roads layer as polygon)
2. The relative traffic density of each road
3. Whether or not a road is paved

There are many potential approaches to accomplish these tasks. A municipality may have a roads layer that has been previously developed. If not, the next steps will give a quick overview of how to create a

roads layer that is relatively accurate and has the necessary attributes. For complete guidance, please refer to Appendix A for detailed guidance.

3.2.4.1 CREATE ROADS BUFFER

Available roads layers are typically line files with attributes about their identity and various classifications. The first step is the width of the road from the linework in order to convert the line layer to a polygon layer that accurately represents the road area of each catchment. In most cases, the specific width of the road is not included as one of the existing attributes in the layer. However, there is often a “Functional Classification” or “road type” attribute that can be used to group similar roads, whether they are Interstate, arterial, or local road. Some of the common road classes used in the Caltrans roads layer are shown in Figure 3-13.



Figure 3-13 Typical road functional classifications

Since roads in similar roads classes will likely have similar widths, the functional classes can be used to estimate the road widths. In GIS, use an aerial imagery layer and the ruler tool to measure the width of 3-5 representative roads for each functional class. Record these measurements in a simple table and take the average of those samples to get an estimated width for each road class (Figure 3-14).

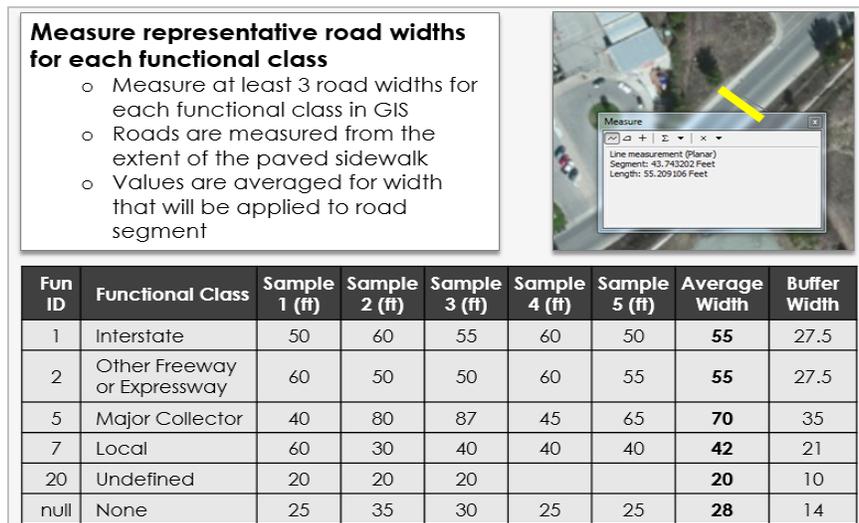


Figure 3-14 Representative road widths by functional class

Use these representative widths to convert the road lines to polygons using the “Buffer” tool. Create another column in this table showing the buffer distance. Since both sides of the line will be buffered, the buffer distance is half of the estimated road width (see Figure 3-14).

As shown in Table 3-1, there are three paved road classes based on relative traffic density: high, moderate, and low. In consultation with traffic experts, assign a traffic density to each road functional class (Figure 3-15). The functional class attributes can be used to make assumptions about road class and traffic density. For example, highways and freeways are likely to have the highest traffic density, with slightly smaller Major Collectors as moderate, and local and undefined roads as low traffic density. Unpaved roads are all classified as low traffic density.

Fun ID	Functional Class	Traffic Density
1	Interstate	High
2	Other Freeway or Expressway	High
5	Major Collector	Moderate
7	Local	Low
20	Undefined	Low
null	None	Low

Figure 3-15 Traffic density by functional class

To create a roads buffer from the roads layer:

- Buffer out the road width using ½ actual road width (Figure 3-16)
- Dissolve areas based on traffic density and whether the road is paved or unpaved

The resulting layer should approximate the width and traffic density of roads throughout the MS4 area. This process will create some overlapping road segments; Appendix A will provide specific guidance to remove these features.

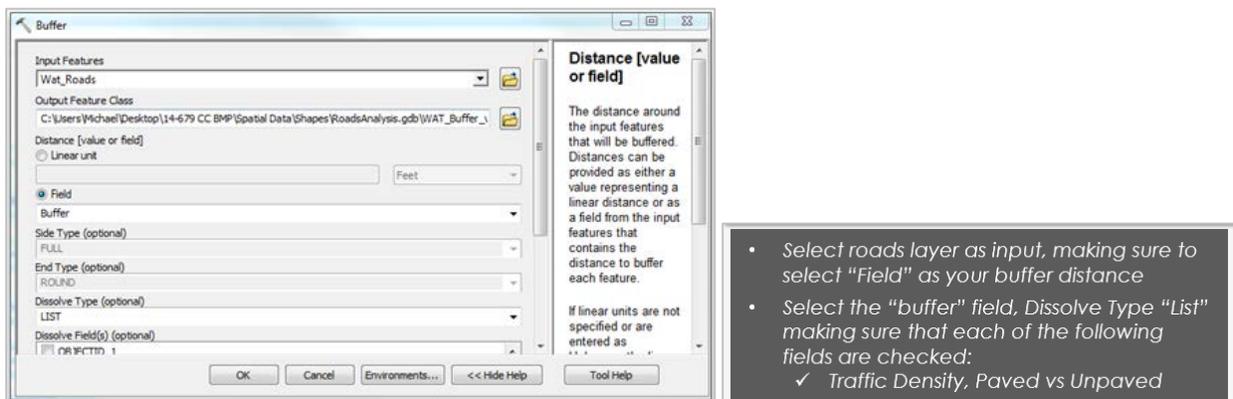


Figure 3-16 Buffer tool

The HTR, MTR, LTR, and rdsUL (sometimes there are no unpaved roads in urban catchments) are then joined with the MS4 area boundary.

- Run the “Union” tool.
- Areas not part of the buffered road surfaces need to be given the attribute “ROW”. When this layer is joined with the parcel-derived land use layer in the next step, Right of Way (ROW) areas will include any areas that do not belong to the buffered roads or to the parcel layer. These ROW

areas don't fit into any single category and can be complicated to address. For the most part they will become part of the road area to which they are adjacent, but in some cases they may better fit one of the other Land Use Definitions. Appendix A provides a process to apply the correct attributes and to account for and delete areas where the roads buffers overlap and create "extra" polygons.

- The final roads layer should look similar to Figure 3-17. The entire MS4 area is represented by either a road class (HTR, MTR, LTR, rdsUL) or ROW area. (In this example there are no unpaved "rdsUL" roads).

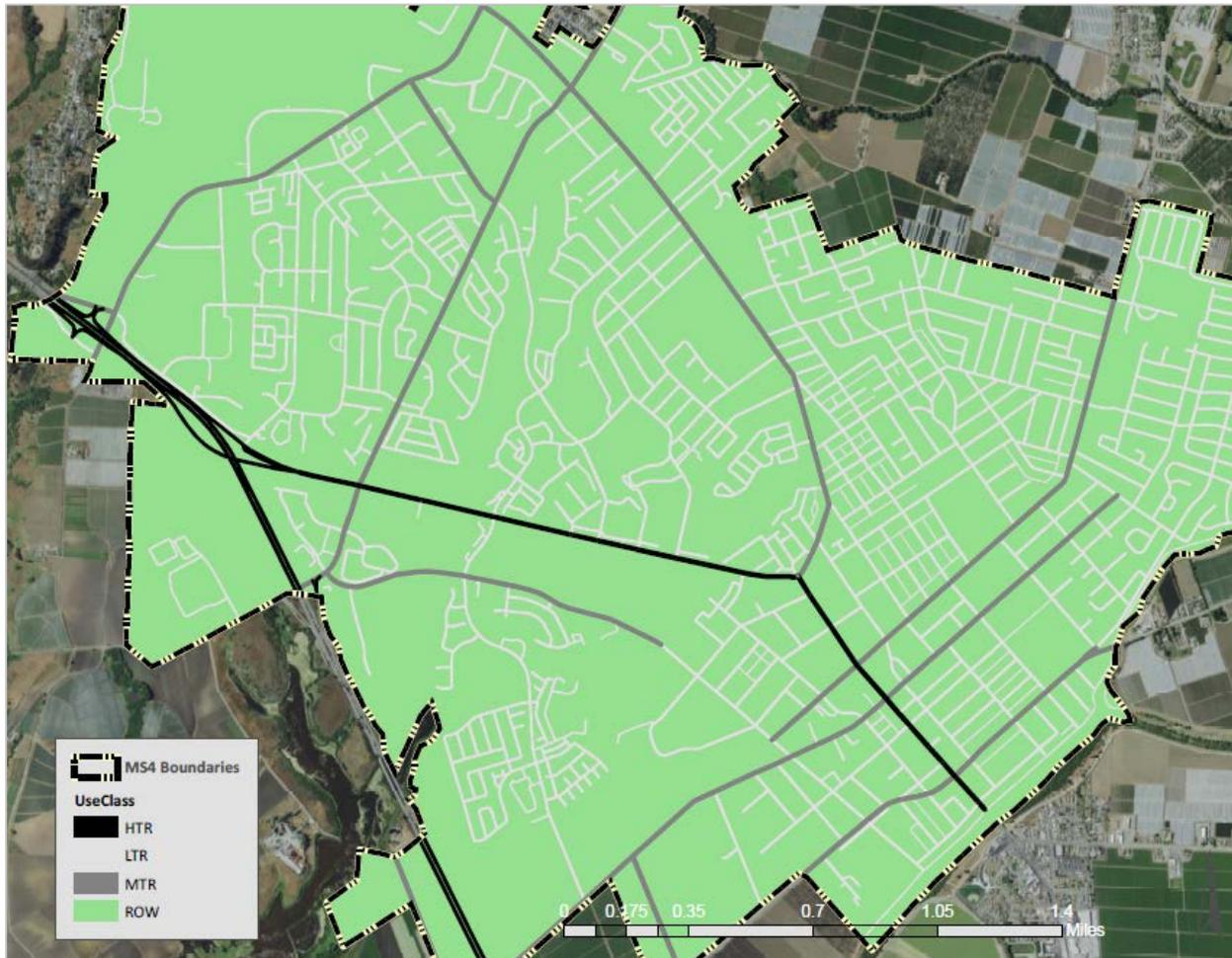


Figure 3-17 Roads Layer

3.2.5 JOIN ROADS AND PARCELS

The reclassified Parcels layer must be joined with the Roads Layer to create a complete land use layer. When joined, these layers will overlap. To create the final layer, the land uses (e.g., roads, ROW or parcel land use) must be prioritized. The roads are the highest priority, as they include a higher proportion of impermeable surfaces, including alley ways and other private roads that may have not been represented in the parcels layer. Next is the parcels layer, and the lowest priority is the ROW, which represent everything that is not a road or a parcel-based land use.

The steps below describe generally how to prioritize these attributes to complete the Land Use layer with roads, parcels and right of way. Greater detail is provided in Appendix A: Land Use Mapping.

1. Run the “union” tool to join the roads/ROW and parcels layers, with both layers maintaining all of their respective attributes. The resulting layer will have features that may have attributes from multiple sources, e.g. both ROW and SFR.
2. Create a field titled “LU_Type” and classify all areas as either “Roads”, “Parcels”, or “ROW” areas, based on the priorities described above. (Note: this step is redundant to steps 5-7, but can greatly help simplify the attributes and the process and help track attribute edits).
 - i. Using field calculator and definition query, select all features that have attributes from the Parcels layer (e.g., APN), and add the attribute “Parcel” in the “LU_Type” field.
 - ii. Select all features with roads attributes (e.g., traffic density), and add the attribute “Roads” in the “LU_Type” field. Some of these selected features will be those that were just labeled “Parcels” in the previous step, but this now overwrites them to prioritize the roads land use.
 - iii. Name all features that are not attributed in “LU_Type” as Parcels or Roads as ROW.
3. Clean up the layer in preparation for the final land use layer.
 - i. Create a new field titled “Combo”. This will serve as the field containing the final attributes for the land use layer.
 - ii. Use a Definition Query to select all records where “LU_Type” is parcels. Copy the reclassified parcel attributes (e.g. “SFR”, “MFR”, “COM”, etc.) using the Field calculator.
 - iii. Use a Definition Query to select all records where “LU_Type” is roads. Copy the roads attributes. They should appear as shown in the Land Use definitions (HTR, MTR, LTR, rdsUL).
 - iv. Use a Definition Query to specify that “LU_Type” is ROW areas. As mentioned above most ROW will end up taking on the attributes of their neighboring roads classes. These area will therefore need to be given a traffic density as well. There is detailed guidance in Appendix A on how to accurately do this, but a simplified solution is to first classify all areas as LTR, since most belong to this class and then looking at the map cherry-pick the outstanding examples where this is not the case and reclassify them accordingly. In certain areas (i.e., large ROW areas adjacent to freeways) the land can be reclassified to “OTH” or a higher traffic density road.

The “Combo” field will now contain one of the 10 land use types for the entire MS4 area. This represents our final land use layer, which can be further refined as users closely review the map. An example output of this process is shown in Figure 3-18.

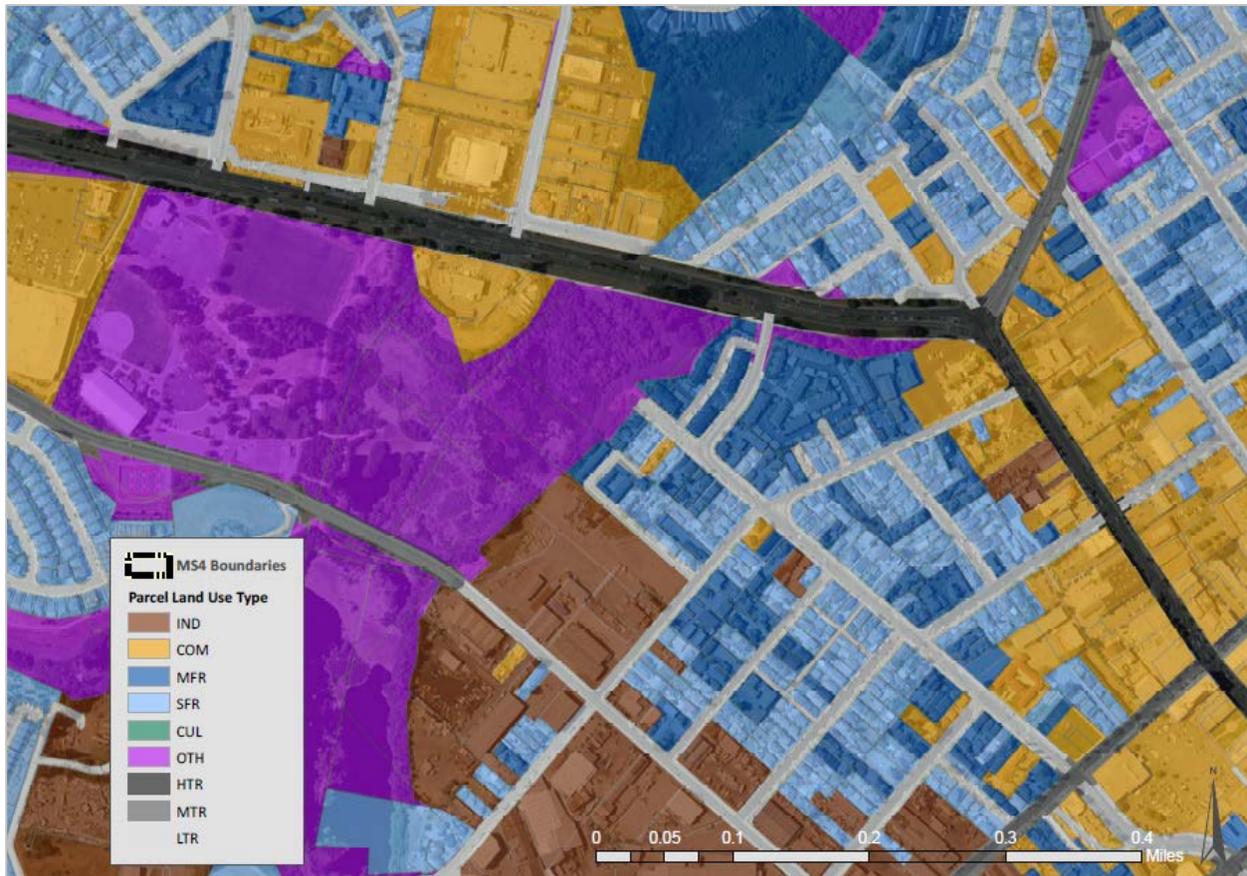


Figure 3-18 Final land use layer

NOTE: this layer is a complete representation of the catchments, their attributes, and all the land uses (parcels, roads, etc.) therein. This layer will contain many attributes, including APN numbers and other potentially useful identifiers, which can be an invaluable resource to stormwater managers in the planning, design and implementation of their stormwater program.

3.2.6 SUMMARIZE AND QAQC

3.2.6.1 SUMMARIZE LAND USE DATA BY CATCHMENT

The following steps will summarize the land use data by catchment:

1. Intersect the catchments layer with the completed land use layer to create a new layer called: Catchment_Parcel_LU_layer.
2. In the resulting layer, add a field titled "ACLU" and calculate the acreage of each feature.
3. Export the attribute table as a "DBASE" file.
4. Open the exported file in Microsoft Excel
5. Select all of the data in the spreadsheet (ctrl A) and insert a pivot table into a new worksheet. In the pivot table editing box, drag the catchID to the ROWS heading and Combo field to the Columns. In the value field we insert the ACLU field and change the field type to sum.

6. The pivot table displays a row for each catchment with columns for each land use type, and values showing the sum of the acres for each of those land uses (Figure 3-19).

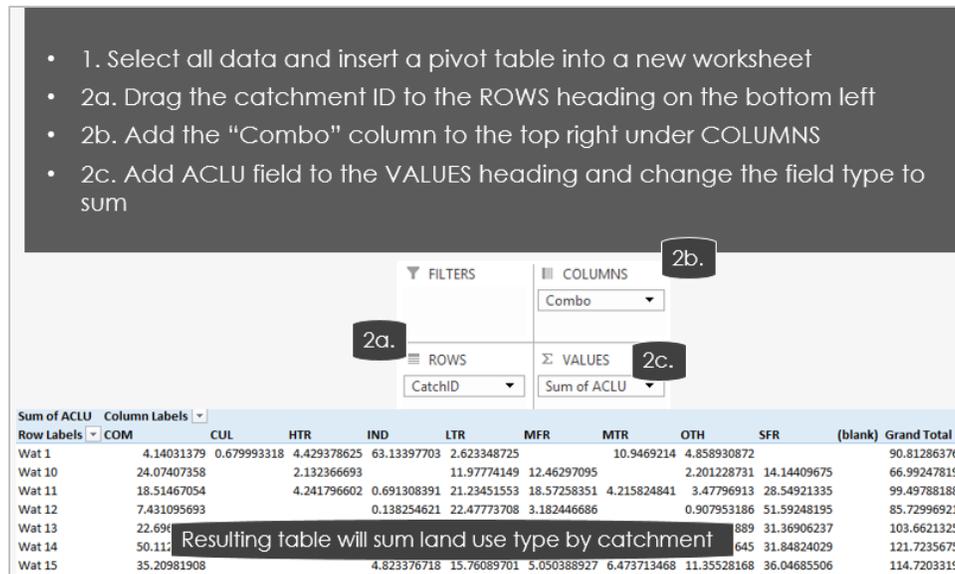


Figure 3-19 Land use pivot table summarizing catchment attributes

3.2.6.2 QAQC LAND USE ATTRIBUTES

The goal of generating these land use attributes is to meet MS4 permit requirements by characterizing each of the catchments with the distribution, in acres, of the 10 identified land use classes (see Table 3-1). The results in the pivot table (Sec. 3.2.6.1) provide this data, but can be improved as there may have been errors in the land use data layer due to imprecise parcel data, overlapping road buffers or any number of other sources. Summing the areas of land uses and comparing this to the calculated catchment area is a simple means for identifying any errors and prioritizing QAQC.

- Copy the pivot table results to a new worksheet
- Sum the area of all the land use types by catchment
- Add an adjacent column with the catchment acreages calculated in GIS.
- Compare these two values as a percent difference to evaluate the data precision.

$$\text{Percent Difference} = \frac{\text{Sum of all Land Use Types} - \text{Catchment Acreage From GIS}}{\text{Catchment Acreage from GIS}}$$

- The land use attribute generation process should result in a very small % difference (<2%). Issues like overlapping parcels or road segments can cause a more significant difference in acreage. We recommend that any catchment with a % difference greater than 5 should be carefully re-evaluated in GIS.
- If there is minimal difference (<5%), look at the catchment on the map and, using best professional judgement, add or subtract the acreage difference to the land use that seems most appropriate given the land uses present in the catchment. The goal is to have the sum of land use acres exactly match the acreage of the catchment.

This process is a general guideline and there are certainly many methods and many levels of effort that one could use to finalize these numbers. Each municipality will be different, and each user will likely need to modify the approach slightly.

4 FINAL MS4 & CATCHMENT ATTRIBUTES

All attributes have now been generated for each catchment (see Figure 3-1) and the attribute table for the final catchment layer can be exported as a table to submit for MS4 permit compliance.

In Excel, create a table with Catchment ID as the unique identifier and copy/paste/fill-in the attributes for each catchment that were generated in Section 3 of this guidance (% impervious, slope, catchment length, precipitation zones, soils classes, and land use acreages). These results can then be joined with the catchment layer in GIS to supplement the original catchment attributes generated in Section 2 of this guidance. At any point, this complete attribute table can be exported to submit for permit compliance and/or used as direct inputs to TELR or other stormwater models. The final MS4 boundary attributes (Figure 4-1), catchment attributes (Figure 4-2) and land use attributes (Figure 4-4) are provided, along with examples (Figures 4-3 and 4-5).

MS4 Boundaries			
Attribute Name	Field Type	Example	Description
MS4Area	Text	Watsonville	The extent of the MS4 area approved by the CCRWQB.
CDP	Text	Watsonville	Census Designated Place
acres	Double	4394	Total area of MS4 in acres

Figure 4-1 Final MS4 boundary attributes

MS4 Catchments (general attributes)			
Attribute Name	Field Type	Example	Description
MS4Area	Text	Watsonville	The extent of the MS4 area
CDP	Text	Watsonville	Census Designated Place
catchID	Text	Wat 47	First three letters of CDP followed by a unique number
acres	Double	95	Catchment area (acres)
outType	Text	Discrete	Outfall type, discrete or distributed
outVerify	Integer	2015	Year that outfall was field verified, leave blank if site was never visited
drainsToRW	Text	Harkins Slough	Indicates NHD receiving water that catchment eventually drains to. If NHD receiving water is not named, indicate "unnamed stream"
drainsToCatch	Text	Wat43	Downstream, terminal catchment by which catchment hydrologic connectivity is defined for subject last catchment.
connect	Double	25%	Catchment hydrologic connectivity (relative %)

Figure 4-2 Final MS4 catchment attributes

MS4Area	CDP	catchID	acres	outType	outVerify	drainsToRW	drainsToCatch	connect
Watsonville	Watsonville	Wat 47	95	Discrete	2015	Harkins Slough	Wat43	100%
Watsonville	Watsonville	Wat 48	135	Distributed		Pajaro River	Wat48	75%
County Of San Luis Obispo	Templeton	Tem 27	112	Distributed		Salinas River	Tem22	40%
Santa Barbara	Santa Barbara	Sba 62	75	Discrete	2016	Mission Creek	Sba60	85%
County of Santa Cruz	Felton	Scr 25	85	Discrete	2015	San Lorenzo River	Scr22	65%

Figure 4-3 Example of final MS4 catchment attributes

MS4 Catchments (land use attributes)			
Attribute Name	Field Type	Example	Description
imp	Double	62%	Percent impervious surface within catchment based on Land Cover layer
SFR	Double	14.49	Single family residential land use within catchment (acres)
MFR	Double	38.00	Multi-family residential land use within catchment (acres)
IND	Double	0.00	Industrial land use within catchment (acres)
COMM	Double	9.50	Commercial land use within catchment (acres)
CULT	Double	1.90	Cultivated land use within catchment (acres)
OTHER	Double	0.00	Other land use within catchment (acres)
HTR	Double	4.75	High traffic density paved roads within catchment (acres)
MTR	Double	4.75	Moderate traffic density paved roads within catchment (acres)
LTR	Double	5.70	Low traffic density paved roads within catchment (acres)
rdsUL	Double	0	Low traffic density unpaved roads within catchment (acres)
precip	Double	2	Precipitation zone (1, 2, 3, 4, 5)
soil	Text	D	Soil type category (A,B,C,D)
catchL	Integer	2300	Catchment length (ft)
catchS	Double	2%	Catchment average slope (%)

Figure 4-4 Final MS4 catchment land use attributes

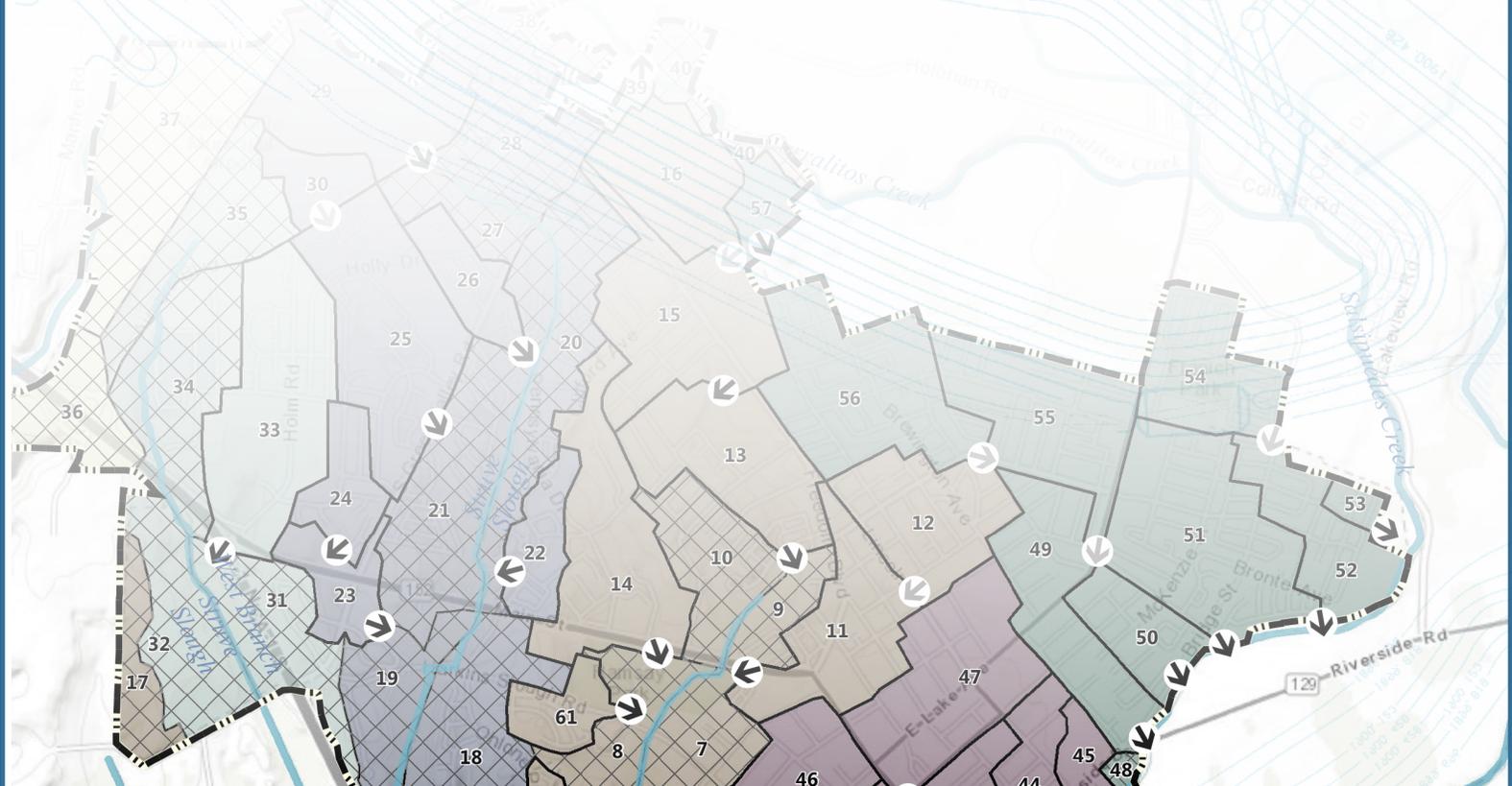
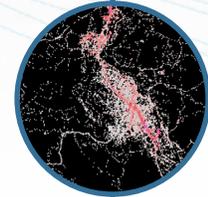
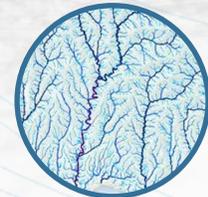
catchID	...	imp	sfr	mfr	ind	comm	cult	other	HTR	MTR	LTR	rdsUL	precip	soil	catchL	catchS
Wat47	...	78%	49.40	19.00	0.00	12.35	11.40	0.00	0.00	0.00	0.00	2.85	3	A	2200	3%
Wat48	...	62%	64.80	20.25	0.00	13.50	24.30	0.00	0.00	4.05	6.75	1.35	3	C	2400	5%
Tem27	...	45%	28.00	0.00	16.80	22.40	36.96	0.00	3.36	2.24	2.24	0.00	3	B	1500	2%
Sba62	...	75%	39.00	7.50	3.75	7.50	9.75	6.00	0.00	1.50	0.00	0.00	2	A	2000	1%
Scr25	...	52%	27.20	17.00	0.00	8.50	28.05	0.00	0.00	3.40	0.85	0.00	4	A	3500	5%

Figure 4-5 Example of final MS4 catchment land use attributes

MS4 CATCHMENT DELINEATION AND
ATTRIBUTE GENERATION GUIDANCE

APPENDIX A:
EXTENDED GUIDANCE
TO REFINE MS4 LAND
USE LAYERS

VERSION 2, APRIL 2016



APPENDIX A: LAND USE MAPPING

This guidance will provide in-depth detail on how to create a complete land use layer for an MS4 area. The instructions assume some proficiency with Esri ArcGIS software. A less detailed guidance of the process is outlined in the MS4 Catchment Delineation and Attribute Generation Guidance. While some components of this document are identical, there are many areas where this guidance provides an extra level of detail. 2NDNATURE has worked through some of the intricacies of mapping tasks and this document is a means of sharing the lessons learned through the process.

1 LAND USE DEFINITIONS

Table 1-1 defines the land use types approved by the regional board.

LU Type	LU Name	Definition
IND	Industrial	The industrial land use includes a wide variety of land uses including manufacturing, power generation, processing of products and more. Pollutant loads from industrial land uses are expected to be the highest of all land use categories.
COM	Commercial	Areas with structures that sell products or provide commercial services. These includes hospitals, shopping centers (and parking lots), schools, grocery stores and motels. Loading from commercial land uses is expected to be lower than industrial, but higher than residential land uses.
MFR	Multi-family Residential	Any areas with multiple residences including townhouses, apartments, mobile home parks, condos or the like. Loading from MFR land use type is below commercial, but higher than SFR.
SFR	Single Family Residential	Any parcel zoned for no more than a single residence. Loading from SFR is lower than MFR.
CUL	Cultivated	Includes all agricultural lands where crops are grown, but not agricultural facilities and dairies (which would be classified as industrial). The pollutant loading from this land is characterized by management practices on soil (e.g., tilling, irrigation) and application of fertilizer.
OTH	Other/Open Space	All undeveloped areas with minimal structures or paved roads. Includes parks, open space easements and campgrounds. Due to the relatively natural conditions, OTH land uses are expected to have minimal loading contributions.
HTR	High Traffic Roads	Roads and adjacent right of way areas that receive relatively high traffic for a given municipality. Road classification systems often identify Freeways, Onramps, and Major arterial roads as high traffic.
MTR	Medium Traffic Roads	Roads and adjacent right of way areas with medium traffic densities for a given municipality. Classifications that can be considered moderate include lower traffic arterial roads and major collectors.
LTR	Low Traffic Roads	Roads and adjacent right of way areas with relatively low traffic density for a given municipality. Typical road descriptions that fall into this category are local, light duty, alleys, and most other undefined road types.
rdsUL	Low Traffic Unpaved	Roads and adjacent right of way areas that are not paved with any impervious surfaces.

Table 1-1 Land use categories

2 LAND USE CROSSWALK

There are many potential sources for land use data. The most important requirement is that the data must have enough detail in order to decipher the 6 parcel-based land use classes (roads are from a separate data source). Many municipalities may have previously-developed land use layers that can be used for this effort, but the data will need to be classified into the land use classes in Table 1-1.

For the sake of consistency and to be comprehensive, we recommend using the “assessor’s parcel layer”. Every municipality has assessor’s parcels, and within this layer there is usually an “assessor’s use code”—a land use code used for tax purposes. This layer is sufficiently detailed, but can often include hundreds of land use codes that must be re-classified into the 6 land use attribute classes. The parcels will most likely not include any of the four roads classes (HTR, MTR, LTR, rdsUL).

To convert assessor’s parcel use codes into the 6 land use attributes, create a crosswalk.

1. Identify the assessors use codes layer in GIS and export the attribute table data to Excel
2. List the assessors use codes in Excel in one column
3. Reclassify each parcel code into one of the land use attributes

When unclear about how to reclassify a parcel, consult the definitions and use best professional judgement.

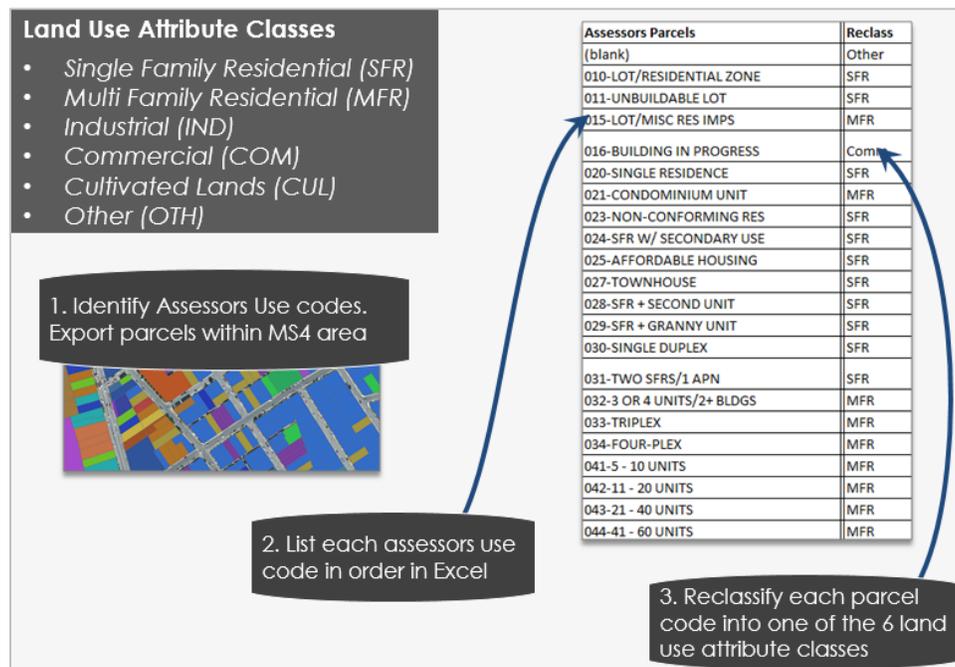


Figure 2-1 Land use crosswalk

2.1 Deciding Which Land Use Type is Correct

While some assessors parcels can easily be identified as one of the 6 land use types (excluding roads), there are many cases where it is not perfectly clear. To aid with this classification, a list of some common assessors parcels land use descriptions is provided for each of the 6 land use definitions. A few tips may also help a user with the decision:

- If it is not completely clear which land use type to classify a particular Assessor's Parcel use code, mark the code "unclassified" in the Reclass field. These can be re-evaluated in GIS.
- When trying to decide between two land use definitions, we recommend selecting towards the land use type with higher pollutant loading (see land use definitions). For example, an assessor's parcel may represent both commercial and industrial land uses. In that case, select Industrial, because of the potentially higher pollutant loading.
- If there are roads within the parcels layer they should be reclassified as "ROW". This will be further discussed as the roads layer is developed.

2.1.1 INDUSTRIAL (IND)

County	Use Code	Parcel Use Description	Reclass
Monterey	6B	Industrial / 6B Light Manufacturing or Light Industrial	IND
Monterey	6D	Industrial / 6D Industrial Park, Research Park, With or without Imps.	IND
Monterey	6C	Industrial / 6C Heavy Manufacturing or Heavy Industrial	IND
Monterey	8F	Miscellaneous / 8F Developed Gas & Oil	IND
Santa Cruz	353	353-LIGHT INDUSTRY	IND
Santa Cruz	932	932-CITY SHOP/YARD	IND
Santa Cruz	934	934-MUNICIPAL UTILITY	IND
Santa Cruz	345	345-OTHER FOOD PROCESSING	IND
Santa Cruz	350	350-HEAVY INDUSTRY	IND
SLO County	305	LIGHT INDUSTRY	IND
SLO County	379	MANUFACTURING	IND
SLO County	381	Automotive - Service Station	IND
SLO County	031	Landfill	IND
SLO County	512	Manufacturing - Heavy	IND
SLO County	511	Manufacturing - Light	IND
SLO County	534	Mining Gypsum	IND
SLO County	531	Mining Sand/Gravel	IND
SLO County	555	Oil Refinery	IND

Table 2-1 Industrial parcel descriptions

2.1.2 COMMERCIAL (COM)

County	Use Code	Parcel Use Description	Reclass
Monterey	7D	Institutional / 7D Churches	COM
Monterey	5Q	OVER 100 UNITS	COM
Monterey	7E	Institutional / 7E Taxable Schools, Colleges, Day Schools, Land and/or Impr.	COM
Monterey	7C	Institutional / 7C Fraternal Organizations	COM
Monterey	7F	Institutional / 7F Hospital Private, Convalescent	COM
Monterey	7G	Institutional / 7G Cemeteries Etc.	COM
Monterey	7H	Institutional / 7H Museums, Libraries	COM
San Benito	CCHU	OTHER FOOD PROCESSING	COM
Santa Cruz	940	SCHOOL DISTRICT APN	COM
Santa Cruz	710	CHURCH	COM
Santa Cruz	171	MULTI OFFICES/1 BLDG	COM
Santa Cruz	151	SUPERMARKET	COM
Santa Cruz	140	DEPARTMENT STORE	COM
Santa Cruz	201	FAST FOOD RESTAURANT	COM
Santa Cruz	200	RESTAURANT	COM
Santa Cruz	172	OFFICE CONDOMINIUM	COM
Santa Cruz	150	GROCERY STORE	COM
Santa Cruz	181	DENTAL OFFICE	COM
SLO County	412	Grocery - Local	COM
SLO County	411	Grocery - Supermarket	COM
SLO County	402	Hospital Private	COM
SLO County	405	Hospital Veterinarian	COM
SLO County	311	Laundromat	COM
SLO County	339	Medical Condo	COM
SLO County	364	Motel W/O Rest 101+ Units	COM
SLO County	337	Office 50+ Units	COM
SLO County	820	School	COM

Table 2-2 Commercial parcel descriptions

2.1.3 CULTIVATED (CUL)

County	Use Code	Parcel Use Description	Reclass
Monterey	4C	Agricultural / 4C Row Crop	CUL
Monterey	4F	Agricultural / 4F Vineyards	CUL
Monterey	4D	Agricultural / 4D Field Crops Alfalfa, Pasture	CUL
Monterey	4E	Agricultural / 4E Feed Lots	CUL
SLO County	030	ORCHARD/LAND ONLY	CUL

Table 2-3 Cultivated parcel descriptions

2.1.4 MULTI-FAMILY RESIDENTIAL (MFR)

County	Use Code	Parcel Use Description	Reclass
Monterey	2G	Multifamily / 2G Condominium and Townhouses, Living Units only. See 8D	MFR
Monterey	2C	Multifamily / 2C 3 or 4 Units	MFR
Monterey	2H	Multifamily / 2H Mobile Home Parks	MFR
Santa Cruz	043	043-21 - 40 UNITS	MFR
Santa Cruz	021	021-CONDOMINIUM UNIT	MFR
Santa Cruz	044	044-41 - 60 UNITS	MFR
Santa Cruz	033	033-TRIPLEX	MFR
SLO County	216	Apartments 21-50 Units	MFR
SLO County	217	Apartments 51-75 Units	MFR
SLO County	136	MH PK - Owned SP	MFR
SLO County	341	Mobile Home Park 1-35 SP	MFR
SLO County	346	Mobile Home Park 200+ Spaces	MFR

Table 2-4 Multifamily residential parcel descriptions

2.1.5 SINGLE FAMILY RESIDENTIAL (SFR)

County	Use Code	Parcel Use Description	Reclass
Monterey	1C	Residential (Urban) / 1C One Single Family Dwelling on One Site	SFR
Monterey	3E	Rural / 3E Improved residential Use Up to 10 acres	SFR
Santa Cruz	020	020-SINGLE RESIDENCE	SFR
Santa Cruz	091	091-COMMON AREA/WITH IMPS	SFR
Santa Cruz	024	024-SFR W/ SECONDARY USE	SFR
SLO County	852	SFR + SECOND UNIT	SFR
SLO County	857	TOWNHOUSE	SFR

Table 2-5 Single family residential parcel descriptions

2.1.6 OTHER (OTH)

County	Use Code	Parcel Use Description	Reclass
Monterey	3J	Rural / 3J Scenic Easement, Open Space, Negative Easement - no subvention	OTH
Monterey	99	Miscellaneous / 99 No other use code applies. Not buildable	OTH
Monterey	3C	Rural / 3C Undeveloped 41 to 300 Acres	OTH
Monterey	3D	Rural / 3D Undeveloped 301 or more acres	OTH
SLO County	039	Open Space Easement	OTH
SLO County	423	Recreational - Camp Ground	OTH

Table 2-6 Other parcel descriptions

3 PARCEL LAND USE QAQC

The crosswalk described above is used to translate all assessors' parcels into the 6 non-road land use categories shown in Table 1-1. The following provides some quick steps to bring the crosswalk into GIS, and to QAQC it.

3.1 Bring the Crosswalk into GIS

1. Save the crosswalk table as a .csv file and add it into GIS.
2. Save the table in GIS as a .dbf (use the "Export" button in the attribute table menu). This allows the user to edit the data in the table and makes it easier to join to other layers.
3. In the Assessor's parcel layer use the "Joins and Relates" tab to join the crosswalk table to the parcel layer, basing the join on the assessor's use codes field.
4. Export the joined layer and title it "Parcel_LU".
5. Display the "Reclass" field from the crosswalk.

3.2 QAQC LU classification

The crosswalk table is a good start to reclassifying a large number of parcels. However, some parcels may not have an accurate assessor's use code to represent the current land use. The land use layer should reflect current use and management. When the land use types that do not meet the land use definitions, the parcel use code should be manually. The following tips some guidance for identifying areas to evaluate and reclassify.

- Use the definition query to specify all "unclassified" land use types. This will highlight all of the parcel codes that were not accurately classified in the crosswalk building step.
 - ❖ Looking at these on a map with aerial imagery or some other municipal reference layer, evaluate each of these "unclassified" use codes to see if they can be classified to one of the 6 land use types
- In some scenarios, one use code may cover multiple land use definitions. For example, parcels with the land use code for "Government" could be a public park (OTH), or a Courthouse (COM).
 - ❖ Note these land use types and use the definition query to isolate them.
 - ❖ Manually reclassify each parcel, or groups of parcels into the correct land use type
- Evaluate the parcel layer for large open space areas (using the underlying aerial imagery) that may be classified as IND or COM.
 - ❖ If it is clear that these areas are not developed and better meet the "Other" land use type definition, reclassify them as such. The goal is to build a land use layer that best represents the current land use and management. If an open space parcel is later developed, the land use layer can be adjusted at that point in time to reflect the new land use and management.
- Ensure that parcels classified as open space are not developed.
- The user should be familiar with their MS4 area. Use best professional judgement to verify that know areas are classified correctly.

Once QAQC'd, the final parcel layer will look similar to Figure 3-1. Note that roads and right of way areas are not yet included.

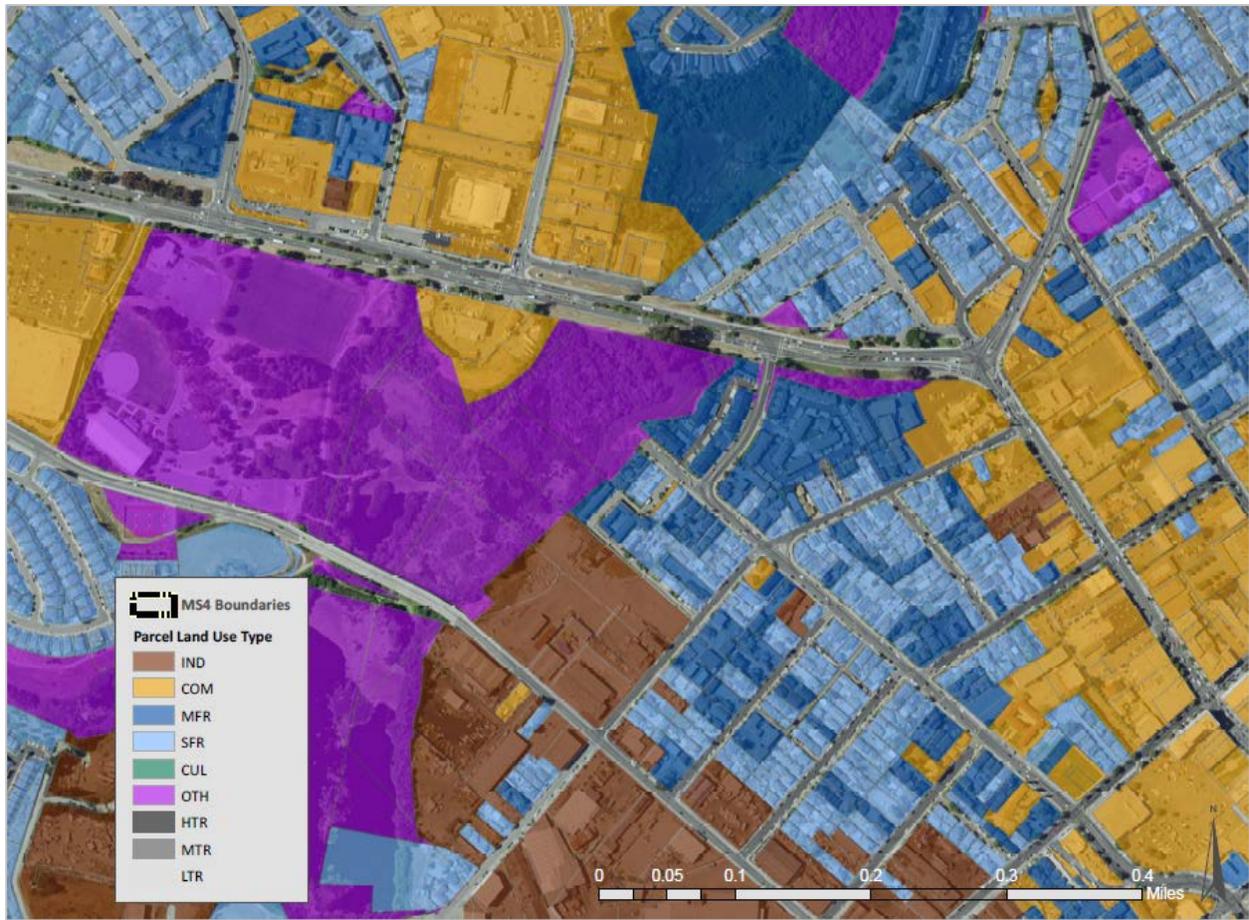


Figure 3-1 Parcel layer map

4 ROADS LAYER

Roads are not usually included in the parcel layer (Figure 4-1) and thus the total acreage of land uses from the assessor's parcel layer will not match the full acreage of the catchments or MS4. Bring the roads data into GIS from another source and generate a roads land use layer with the following information:

1. Acreage of roads within each catchment (roads layer as polygon)
2. The relative traffic density of each road
3. Whether or not a road is paved

There are many potential approaches to accomplish these tasks. A municipality may have a roads layer that has been previously developed. If not, the next steps will give a quick overview of how to create a roads layer that is relatively accurate and has the necessary attributes. For complete guidance, please refer to Appendix A for detailed guidance.



Figure 4-1 Parcel layer map showing data gaps for roads and right of way

4.1 Create Roads Buffer

Available roads layers are typically line files with attributes about their identity and various classifications. The first step is the width of the road from the linework in order to convert the line layer to a polygon layer that accurately represents the road area of each catchment. In most cases, the specific width of the road is not included as one of the existing attributes in the layer. However, there is often a “Functional Classification” or “road type” attribute that can be used to group similar roads, whether they are Interstate, arterial, or local road. Some of the common road classes used in the Caltrans roads layer are shown in Figure 4-2.



Figure 4-2 Typical road functional classes

Since roads in similar roads classes will likely have similar widths, the functional classes can be used to estimate the road widths. In GIS, use an aerial imagery layer and the ruler tool to measure the width of 3-5 representative roads for each functional class. Record these measurements in a simple table and take the average of those samples to get an estimated width for each road class (Figure 4-3).

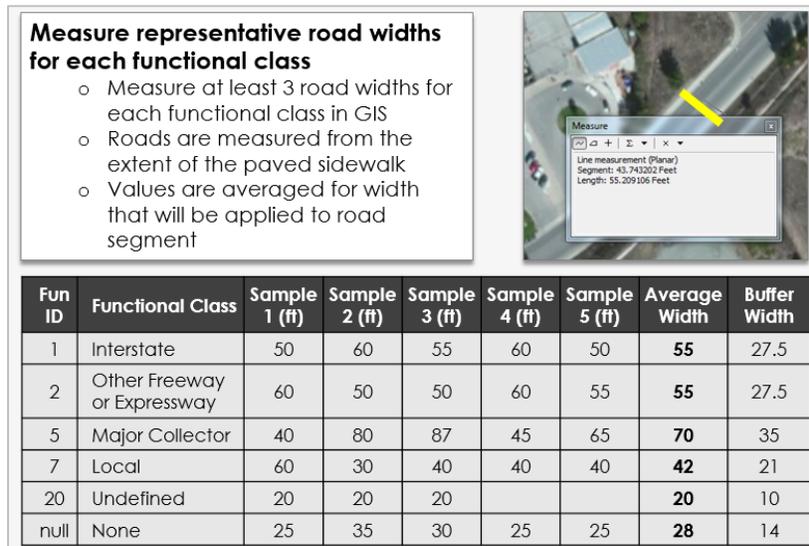


Figure 4-3 Representative road widths by functional class

Use these representative widths to convert the road lines to polygons using the “Buffer” tool. Create another column in this table showing the buffer distance. Since both sides of the line will be buffered, the buffer distance is half of the estimated road width (see Figure 4-3).

As shown in Table 3-1, there are three paved road classes based on relative traffic density: high, moderate, and low. In consultation with traffic experts, assign a traffic density to each road functional class (Figure 4-3). The functional class attributes can be used to make assumptions about road class and traffic density. For example, highways and freeways are likely to have the highest traffic density, with slightly smaller Major Collectors as moderate, and local and undefined roads as low traffic density. Unpaved roads are all classified as low traffic density.

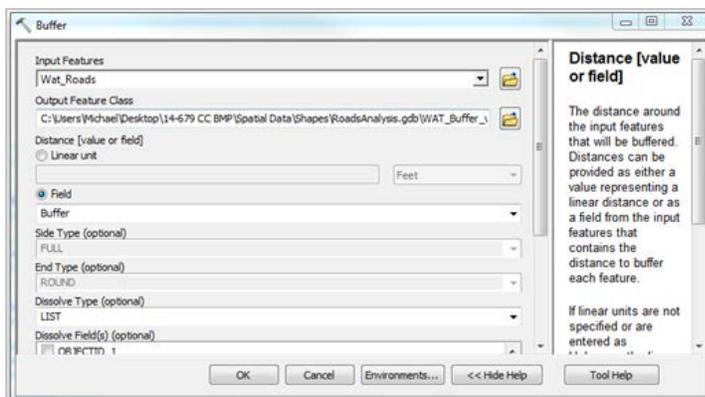
Fun ID	Functional Class	Traffic Density
1	Interstate	High
2	Other Freeway or Expressway	High
5	Major Collector	Moderate
7	Local	Low
20	Undefined	Low
null	None	Low

Figure 4-2 Traffic density by functional class

In the attribute table of the roads line file create a text field titled “Roads”. We will give this all the necessary road attributes. For paved roads copy over the traffic density. Make sure to use the correct road classes provided in the land use type definitions (HTR, MTR, LTR). All unpaved roads should be given the attribute “rdsUL”. Similarly, create a field titled “buffer” and add the ½ buffer widths there.

With all the attributes in place, the next step is to create a roads buffer from the roads layer.

- Buffer out the road width (buffer field should be ½ actual road width)
- Dissolve areas based on the “Roads” field that contains the four road classes. *Do not dissolve on any additional fields, resulting layer would have extra road segment duplicates.



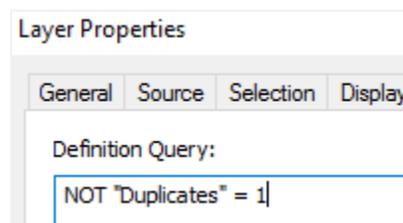
- Select roads layer as input, making sure to select “Field” as your buffer distance
- Select the “buffer” field, Dissolve Type “List” making sure that each of the following fields are checked:
 - ✓ Traffic Density, Paved vs Unpaved

Figure 4-3 Buffer tool.

4.1.1 REMOVE ROAD DUPLICATES

The roads field layer with the attributes HTR, MTR, LTR, and rdsUL (sometimes there are no unpaved roads in urban catchments) has been created. In some cases, the buffering process may have created two road segments on top of each other in the same location (duplicate areas). These need to be removed, to ensure the acreage calculations for roads are not too high as any location where roads meet will have double the road area. There are different strategies that can be used to remove duplicates and these vary depending on the GIS software and licenses. The method below removes these features without an advanced GIS license.

- Run the union tool with the buffered roads layer and the MS4 boundary. This step will make it possible to duplicate features without deleting the entire road segment.
- In the “Roads” field of the resulting layer, give all areas that were not a part of the roads layer the attribute “ROW”.
- This layer should now contain four road classes and “ROW” areas.
- Add an integer field titled “Duplicates” to attribute table.
 - Use the Definition Query to remove all features that are duplicates. Use the following Query:



- The duplicate features were a result of the intersection of roads with different attributes. When a HTR road meets another road (MTR, LTR, rdsUP), there will be a small duplicate area. Where these areas overlap, the feature to be deleted must be specified.
- In all cases, delete the lower traffic density road. Use the table below to decide which features to keep.

Intersection	
<i>Keep</i>	<i>Delete</i>
HTR	MTR
HTR	LTR
HTR	rdsUL
MTR	LTR
MTR	rdsUL
LTR	rdsUL

- On the map, click on an area where two roads intersect. For example, where an HTR meets a MTR. In the attribute table two features should be selected.
 - Mark the MTR feature as “1” in the “Duplicates” field.
 - That feature will automatically be removed based on the definition query. All the duplicate features where HTR meets MTR have now been removed.
 - Repeat the same process by marking a “1” next to each other possible case of duplicate features shown in the “Intersection” table above.

- The only remaining duplicate features will be where 3 road types overlap. The same process can be used to delete duplicates from these areas.
- Once complete, there should be no duplicate features in the roads/row layer. A simple QAQC can be used to compare the area of the MS4 boundary to our roads/MS4 layer. (The layers may need to be intersected, as there could be roads out of the MS4 area at this point.)

The final roads/ROW layer should look similar to Figure 4-5. The entire MS4 area is represented by either a road class (HTR, MTR, LTR, rdsUL) or ROW area. (In this example there are no unpaved “rdsUL” roads).

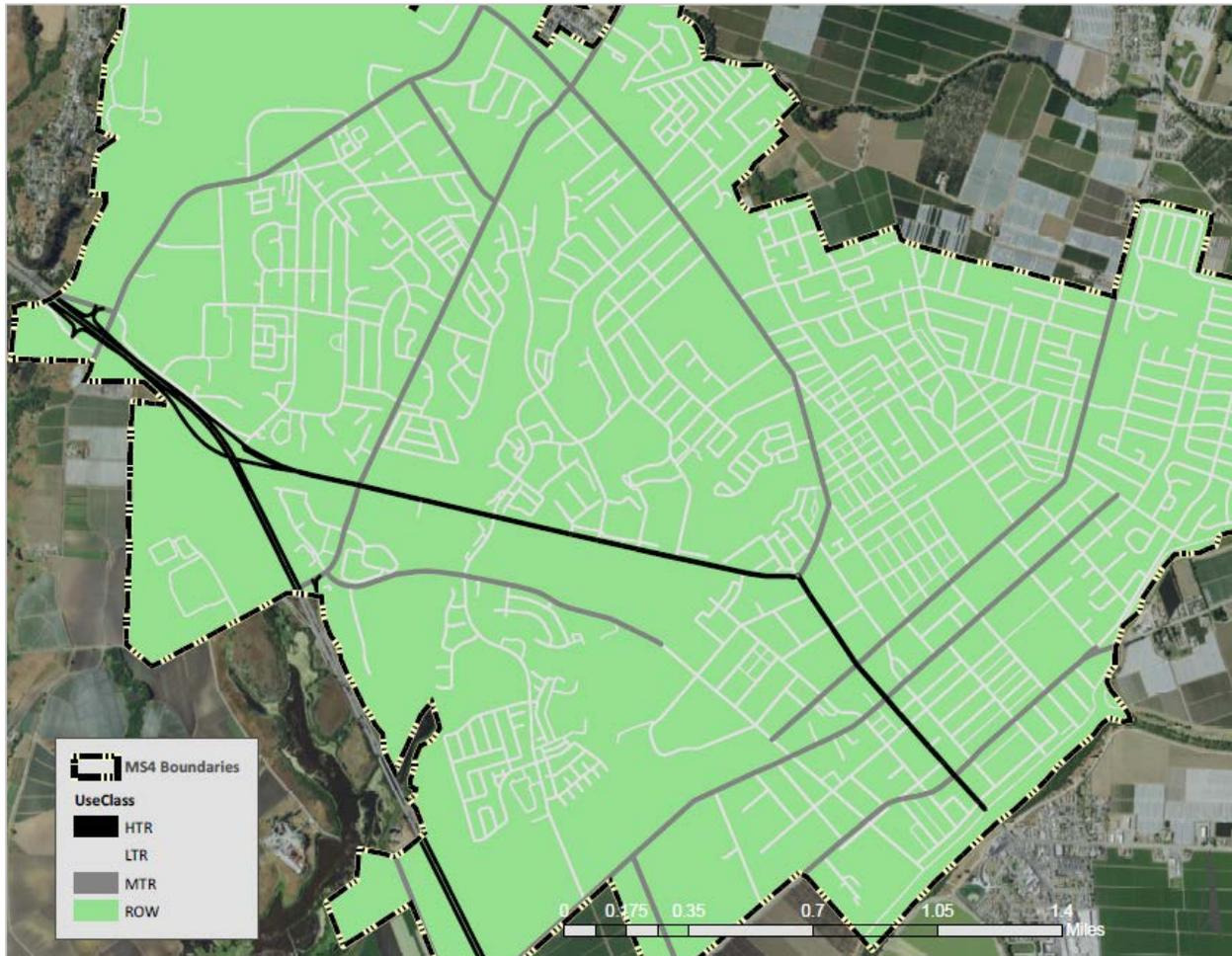


Figure 4-4 Roads Layer

5 JOIN ROADS AND PARCELS

The reclassified Parcels layer must be joined with the Roads Layer to create a complete land use layer. When joined, these layers will overlap. To create the final layer, the land uses (e.g., roads, ROW or parcel land use) must be prioritized. The roads are the highest priority, as they include a higher proportion of impermeable surfaces, including alley ways and other private roads that may have not been represented in the parcels layer. Next is the parcels layer, and the lowest priority is the ROW, which represent everything that is not a road or a parcel-based land use.

The steps below describe generally how to prioritize these attributes to complete the Land Use layer with roads, parcels and right of way.

5.1 Land Use Type

- Run the “union” tool to join the roads/ROW and parcels layers, with both layers maintaining all of their respective attributes. The resulting layer will have features that may have attributes from multiple sources, e.g. both ROW and SFR.
- To simplify this, create a field titled “LU_Type” and classify all areas as either “Roads”, “Parcels”, or “ROW” areas, based on the priorities described above.
 - Using field calculator and definition query, select all features that have attributes from the Parcels layer (e.g. APN), and add the attribute “Parcel” in the “LU_Type” field.
 - Select all features with roads attributes (e.g. traffic density), and add the attribute “Roads” in the “LU_Type” field. Some of these selected features will be those that were just labeled “Parcels” in the previous step, but this now overwrites them as roads are the priority land use.
 - All features that are not attributed in “LU_Type” as Parcels or Roads can be named as ROW.

5.2 ROW Classification

While the total area of ROWs—right of way areas not included in parcel or roads layer—is usually quite small (5-10% of total MS4 area), a process is still needed to assign these areas land use attributes so they can be included in the stormwater load models and so an MS4’s land use map does not have conspicuous blank areas. The following steps will help isolate these areas to apply appropriate attributes.

- Use the definition query to specify “LU_Type”=“ROW”. Export all ROW layers as a new layer.
- Since the majority of the ROW areas represent things like sidewalks adjacent to low traffic roads, or other roads margins, work towards incorporating these areas into the roads classes that best suits them. Start by giving these areas a traffic density.
- Using the road lines layer created in Section 4.1, buffer the layer to incorporate all “ROW” areas.
 - In the buffer tool, instead of selecting a field to buffer, select a distance of 100ft.
 - Dissolve attributes based on the “Roads” field to preserve the traffic density type previously calculated.
 - Follow the same steps from the previous section to remove duplicate features.
 - The result is a general layer to apply road classes to the ROW areas.
- Intersect the ROW areas with the new buffered road class layer.

- Add a new field titled "ROW". Copy all of the attributes from the "Roads" layer including the 4 road classifications and "ROW" areas. Delete all of the other fields.
- Any remaining ROW areas that were not intersected with a road area can be classified based on adjacent land use.

5.2.1 CLEANING UP THE ROW LAYER

While this buffering and intersecting process effectively assigned most ROW areas to the road class land use type of its neighboring polygon, some ROW areas might be better represented as a land use type other than roads. The following are a few tips for further cleaning and reclassifying these ROW areas.

- ROW areas adjacent to freeways are often better classified as open space (or "other") than as HTR. These areas can be reclassified into the appropriate land use category by looking at the layer with an aerial image and manually selecting and renaming ROW polygons of interest. In this case, the large areas adjacent the freeway can be given the attribute of "OTH".



Figure 5-1 ROW adjacent to high traffic roads

- If the user wants to refine the "ROW" areas further, all areas can be delineated into the most representative land use types. The level of refinement depends on how much time and resources are available. In the example below, areas adjacent to the road keep their classification based on traffic density. However, a few sections were reclassified as "OTH" because in reality the ROW areas were open space.

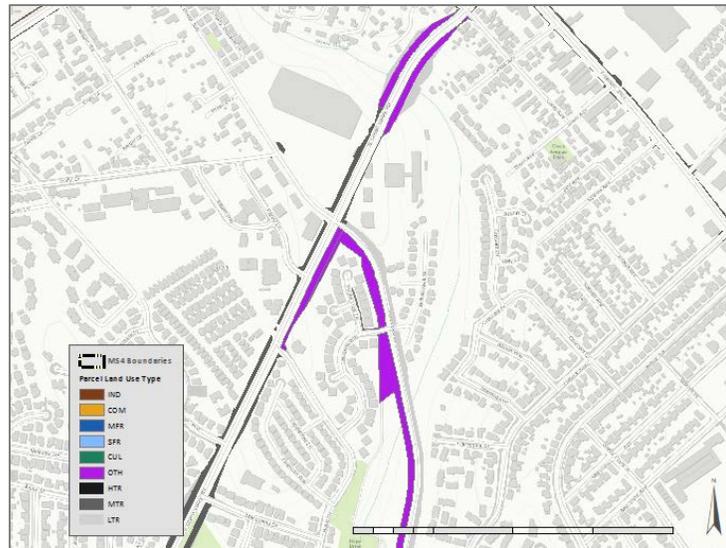


Figure 5-2 ROW adjacent to moderate traffic density roads

- Once the “ROW” areas have been appropriately reclassified, join the layer with parcels and road layer by using the. Remove the definition query from the parcel/roads land use layer (introduced in the first step under 5.2). Run the union tool with the parcel/roads layer and the newly revised “ROW” layer.
- The result is now an integrated land use layer, where each “ROW” feature has been assigned a land use type.

5.3 Final Land Use Layer

Clean up the layer in preparation for the final land use layer.

- Create a new field titled “Combo”. This will serve as the field containing the final attributes for the land use layer.
- Use a Definition Query to specify all records where “LU_Type” is ROW areas. These should be the same areas that were assigned land use attributes in section 5.2. Copy over ROW attributes to the combo layer.
- Use a Definition Query to select all records where “LU_Type” is parcels. Copy the reclassified parcel attributes (e.g. “SFR”, “MFR”, “COM”, etc.) using the “field calculator”.
- Use a Definition Query to select all records where “LU_Type” is roads. Copy the roads attributes. They should appear as shown in the Land Use definitions (HTR, MTR, LTR, rdsUL).

The “Combo” field will now contain one of the 10 land use types for the entire MS4 area. This represents the final land use layer which can be improved as users see fit by looking closely at their map and reclassifying features using best professional judgement. An example output of this process is shown below.

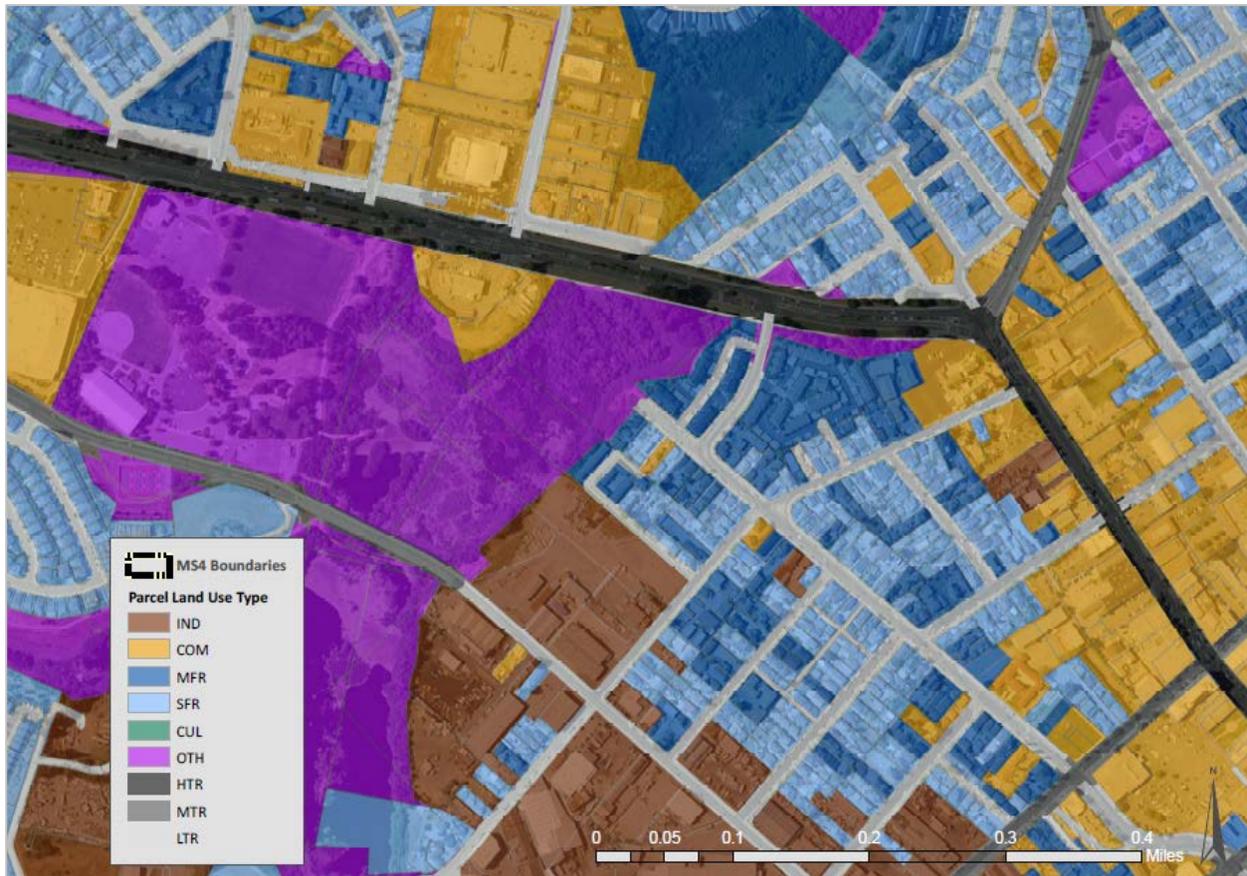


Figure 5-3 Final land use layer

NOTE: this layer is a complete representation of the catchments, their attributes, and all the land uses (parcels, roads, etc.) therein. This layer will contain many attributes, including APN numbers and other potentially useful identifiers, which can be an invaluable resource to stormwater managers in the planning, design and implementation of their stormwater program.

6 SUMMARIZE AND QAQC

6.1 Summarize Land Use Data By Catchment

The following steps will summarize the land use data by catchment:

1. Intersect the catchments layer with the completed land use layer to create a new layer called: Catchment_Parcel_LU_layer.
2. In the resulting layer, add a field titled "ACLU" and calculate the acreage of each feature.
3. Export the attribute table as a "DBASE" file.
4. Open the exported file in Microsoft Excel
5. Select all of the data in the spreadsheet (ctrl A) and insert a pivot table into a new worksheet. In the pivot table editing box, drag the catchID to the ROWS heading and Combo field to the Columns. In the value field we insert the ACLU field and change the field type to sum.
6. The pivot table displays a row for each catchment with columns for each land use type, and values showing the sum of the acres for each of those land uses (Figure 3-19).

The figure below shows the raw data summarized by catchment.

- 1. Select all data and insert a pivot table into a new worksheet
- 2a. Drag the catchment ID to the ROWS heading on the bottom left
- 2b. Add the "Combo" column to the top right under COLUMNS
- 2c. Add ACLU field to the VALUES heading and change the field type to sum

Sum of ACLU	Column Labels										
Row Labels	COM	CUL	HTR	IND	LTR	MFR	MTR	OTH	SFR	(blank)	Grand Total
Wat 1	4.14031379	0.679993318	4.429378625	63.13397703	2.623348725		10.9469214	4.858930872			90.81286376
Wat 10	24.07407358		2.132366693		11.97774149	12.46297095		2.201228731	14.14409675		66.99247819
Wat 11	18.51467054		4.241796602	0.691308391	21.23451553	18.57258351	4.215824841	3.47796913	28.54921335		99.49788188
Wat 12	7.431095693			0.138254621	22.47773708	3.182446686		0.907953186	51.59248195		85.72996921
Wat 13	22.696							889	31.36906237		103.6621325
Wat 14	50.117							645	31.84824029		121.7235675
Wat 15	35.20981908			4.823376718	15.76089701	5.050388927	6.473713468	11.35528168	36.04685506		114.7203319

6.2 QAQC Land Use Attributes

The goal of generating these land use attributes is to meet MS4 permit requirements by characterizing each of the catchments with the distribution, in acres, of the 10 identified land use classes (see Table 3-1). The results in the pivot table (Sec. 3.2.6.1) provide this data, but can be improved as there may have been errors in the land use data layer due to imprecise parcel data, overlapping road buffers or any number of other sources. Summing the areas of land uses and comparing this to the calculated catchment area is a simple means for identifying any errors and prioritizing QAQC.

- Copy the pivot table results to a new worksheet
- Sum the area of all the land use types by catchment
- Add an adjacent column with the catchment acreages calculated in GIS.
- Compare these two values as a percent difference to evaluate the data precision.

$$\text{Percent Difference} = \frac{\text{Sum of all Land Use Types} - \text{Catchment Acreage From GIS}}{\text{Catchment Acreage from GIS}}$$

- The land use attribute generation process should result in a very small % difference (<2%). Issues like overlapping parcels or road segments can cause a more significant difference in acreage. We recommend that any catchment with a % difference greater than 5 should be carefully re-evaluated in GIS.
- If there is minimal difference (<5%), look at the catchment on the map and, using best professional judgement, add or subtract the acreage difference to the land use that seems most appropriate given the land uses present in the catchment. The goal is to have the sum of land use acres exactly match the acreage of the catchment.