Moraga Storm Drain Master Plan

Town of Moraga

Public Works Department/Engineering Division

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Schaaf & Wheeler
CONSULTING CIVIL ENGINEERS

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List of Acronyms

BCDC	Bay Area Conservation and Development Commission
CCCWP	Contra Costa Clean Water Program
CCTV	Closed-circuit television (video surveillance)
CFS	cubic feet per second
CGP	Construction General Permit
CIP	capital improvement program
CMP	corrugated metal pipe
DHI	Danish Hydraulic Institute
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	flood insurance rate map
FIS	flood insurance study
FT	feet
GIS	geographic information system
HEC-HMS	hydrologic modeling system
HEC-RAS	river analysis system
HGL	hydraulic grade line
LID	low impact development
LiDAR	Light Detection and Ranging
MAP	mean annual precipitation
MRP	Municipal Regional Permit
MU	MIKE URBAN
NAVD	North American Veridical Datum of 1988
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
RCP	reinforced concrete pipe
RJA	RJA Group Incorporated
ROW	Right of Way
RWCQB	Regional Water Quality Control Board
S&W	Schaaf & Wheeler
SDMP	storm drain master plan
SQ.MI	square mile
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
V&A	V&A Inc. Civil and Transportation Engineers

Executive Summary

This storm drain master plan (SDMP) establishes a prioritized capital improvements program to update stormwater conditions within the Town of Moraga (Town). The identified projects within the storm drain system prolong the life of existing infrastructure and provide a 10-year (10% annual exceedance) storm capacity throughout the Town for public facilities. The identified projects within the creek culvert system provide a 100-year (1% annual exceedance) storm capacity. These levels of service provide cost effective drainage protection and at the same time help the Town of Moraga keep up to common standards adopted throughout the Bay Area for storm drainage.

Study Objectives

The basic objective of this master plan document is to provide an examination of the storm drain system within the Town limits and recommend improvements to achieve the appropriate level of service of the storm drain and creek culvert systems within the Town limits. The following tasks were undertaken and accomplished as part of this study:

- Transposition of paper maps to electronic data in geographic information systems (GIS) format
- Collection of field data to fill in data gaps and verify information contained in paper maps
- Build an existing conditions model of the storm drainage network
- Collection of creek culvert data to build creek models
- Video inspection of storm drain system under 2015 Pavement Reconstruction Projects
- Analysis of the performance of existing storm drainage systems
- Analysis of the performance of creek culvert system
- Identification of capital improvements to reduce stormdrain overflows and creek flooding
- Prioritization based capital improvements for risk reduction and cost benefit
- Determination of project costs based on current Engineering News-Record (ENR) indices.

Background

The Town's system is integrated between storm drain pipes, ditches, and creeks. In some instances, creeks are routed through large underground culverts, such as Laguna Creek. The steep terrain transports sediment and debris through the pipe network system which can limit the capacity. Field condition assessment noted that although the majority of the pipes are in good condition, some of the pipes would benefit from maintenance to remove debris.

Work Products

This master plan is intended to function as a multipurpose resource guide for the Town of Moraga's stormwater solutions. Town planners and engineers responsible for the stormwater capital improvements should find sufficient background information and data in this document to serve as the basis for storm drainage Capital Improvement Program (CIP) implementation and/or modification. Improvement descriptions, maps, and modeling data have been included in the appendices of this report.

Study Findings

Detailed review, field investigations, analysis and modeling of the area's storm drainage system and creek culverts led to several conclusions discussed in Chapters 5, 6 and 8. These conclusions have been utilized to recommend improvements to the system to address the capacity and condition of the storm drain system. The recommended improvements are highly conceptual in nature and are based on currently-available information. Modeling results for future conditions do not indicate any specific required improvements at this time, however; future development will decrease infiltration rates and increase stormwater flows which will have an impact on the capacity of the existing system. New developments should be analyzed in more detail to better understand the impacts on the existing storm drain system. A Nexus Study is currently underway by Seifel Consulting to develop an impact fee for development based on the increase in stormwater flows from future development.

This master plan recommends $26 –Million worth of improvements based on the capacity, condition, street pavement, reoccurring problems, and creek culverts. The majority of projects are related to capacity and creek culverts. A small portion is related to condition, streets, and reoccurring problems. The recommended improvements include some projects that are located under private parcels. For the purpose of this report, any pipe under a private parcel is considered private, even if an easement and/or dedication exists for that pipe. The Town should conduct further investigations into whether or not easements were accepted for those pipes. The $12–Million in creek culvert improvements recommended in this master plan are based on the capacity of the creek culverts to convey the published FEMA 100-year flows.

Table ES-1: Storm Facility CIP Summary

Storm Drain System	High Priority	Moderate Priority	Low Priority	All
	Cost	Cost	Cost	Cost
Capacity	$2,850,000	$5,110,000	$2,950,000	$10,910,000
Condition	$1,440,000	$40,000	$750,000	$2,230,000
Street Pavement	$280,000	$100,000	$150,000	$530,000
Recurring Problems	---	$150,000	---	$150,000
Creek Culverts	$4,290,000	$5,530,000	$2,290,000	$12,110,000
Total	**$8,860,000**	**$10,930,000**	**$6,140,000**	**$25,930,000**

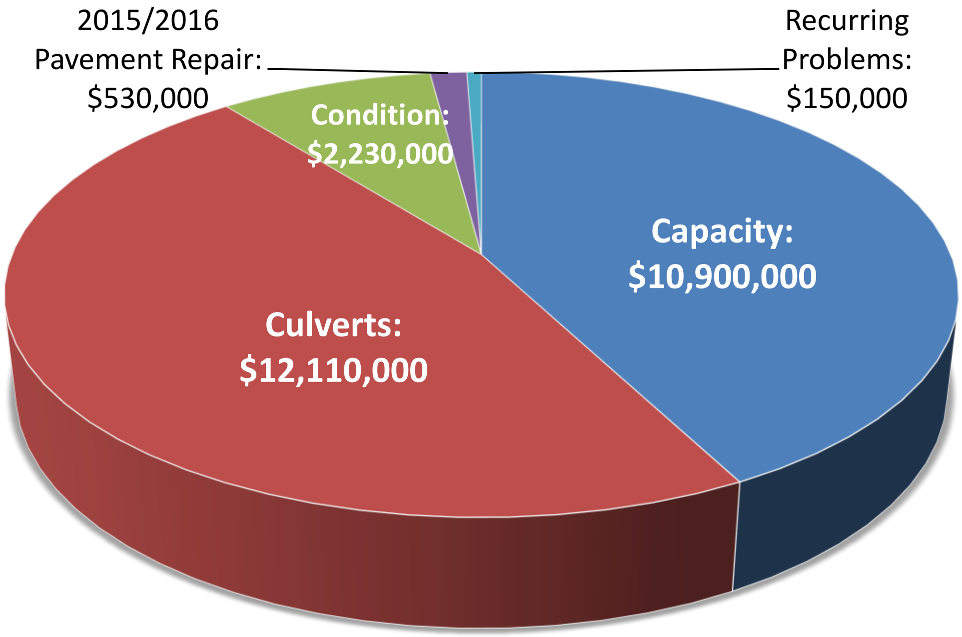

Figure ES-1: Storm Facility CIP Breakdown by Category

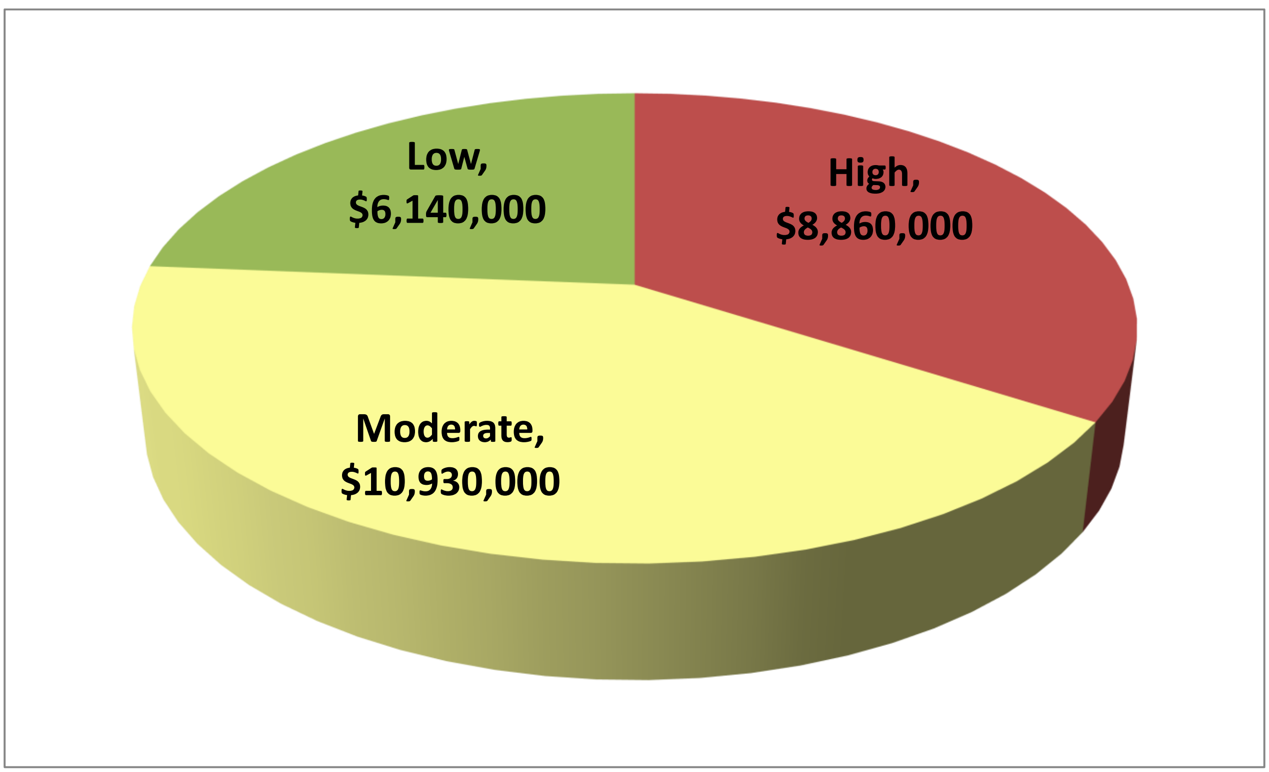

Figure ES-2: Project Cost Breakdown by Priority

Annual Maintenance, Inspection, and Asset Replacement

In addition to the identified improvement projects, it is recommended that the Town set aside an annual budget of $240,000 to televise, clean, and replace/repair any pipes that are found to be in poor condition. Pipes should be televised under the streets to be repaired in the following year in order to coordinate pavement repair with storm drain repairs.

Title and Easement Research

There are 17 projects rated high and moderate priority that contain pipes under private parcels. The cost of these projects total about $13 million. This amount is over half of the costs of the high and moderate priority projects. It is recommended that the Town begin investigating the underlying property ownership interests. It is estimated that it will cost approximately $40,000 for the Town to hire a consultant to identify the property rights for the 17 high and moderate projects.

Conclusion

This Storm Drain Master Plan (SDMP) provides a tool for citizens and officials of Moraga to use in their efforts to reduce both recurring problems, and the possibility of more serious stormwater related hazards to private and/or public property. This study and proposed CIP is merely the conceptual starting point. It is anticipated that Town staff and/or their consultants will perform a more detailed study or alternatives analysis to identify the most affordable and effective improvements with information gathered as part of the design process (detailed topography, utility conflicts, easements, etc.). Additional study will also clarify further which facilities are Town-owned and which are private.

Chapter 1. Introduction

1.1. Overview

This Storm Drain Master Plan identifies the storm drain and creek culvert systems improvements within the Town of Moraga. It primarily focuses on Town owned drainage facilities (with some private facilities referenced where impacts affect public streets) and should be used to guide the Town in planning, financing, engineering, and maintaining drainage infrastructure. Each chapter of this report helps the Town identify problems, manage resources, and provide cost-effective and comprehensive solutions.

This chapter provides a general discussion of storm drainage and creek flood management issues currently affecting the Town of Moraga; along with historic flooding and a summary timeline of regulatory floodplain mapping efforts completed within the Town. It also describes the Master Plan objectives, explains the criteria used to evaluate storm drain and culvert systems performances, and presents a summary of data acquired as part of the Town's Storm Drain Master Plan (SDMP). Existing hydrologic and environmental settings of the Town are described along with creek flood protection and storm drain facilities.

1.2. Setting

Moraga encompasses many hillside areas and is bordered by the cities of Lafayette, Orinda and Unincorporated Contra Costa County. It is relatively sloped, with elevations ranging from 460 feet North American Vertical Datum (NAVD), to about 1,200 feet NAVD.

1.3. Climate

The climate of Moraga is marine-influenced with an average summertime high temperature of 80°F and an average low of 50°F; dropping to an average winter nighttime low temperature of 35°F and an average high of 56°F. Mean annual precipitation is 28-inches, with the majority of that precipitation falling from November through March. Precipitation occurs entirely as rainfall. Snowmelt is not a hydrologic process that significantly affects runoff in the Town.

1.4. Flood Protection Facilities

Precipitation that falls within Moraga generates stormwater runoff. This runoff is conveyed into a number of manmade drainage systems that discharge to local creeks that eventually drain to the Upper San Leandro Reservoir, with the exception of Las Trampas Creek, which drains towards Lafayette. Some components of these systems are owned by the Town, while others are private. Determining private/Town ownership is complex and often requires detailed study and legal analysis. As part of this project, Ruggeri-Jensen-Azar (RJA) was hired to investigate easement maps to better understand what part of the system has recorded easements and/or dedications. Further work will determine which easements have been accepted by the Town.

The private/Town ownership designations presented in this report are preliminary and should be further investigated prior to design. Storm drain systems can interact with one another, and potential improvements to one system may impact the performance of other systems. The total study area is roughly 9.5 square miles (6,050 acres). While the majority of the Town has traditional curb and gutters, there are some areas that consist of roadside ditches with driveway culverts. This more rural drainage layout tends to attenuate runoff by slowing velocities and creating surface ponding.

In addition to storm drains, creek flood protection is provided to the Town by the Moraga and Laguna Creek systems that convey storm-generated runoff to the Upper San Leandro Reservoir. Figure 1-1 shows the Town of Moraga's drainage system.

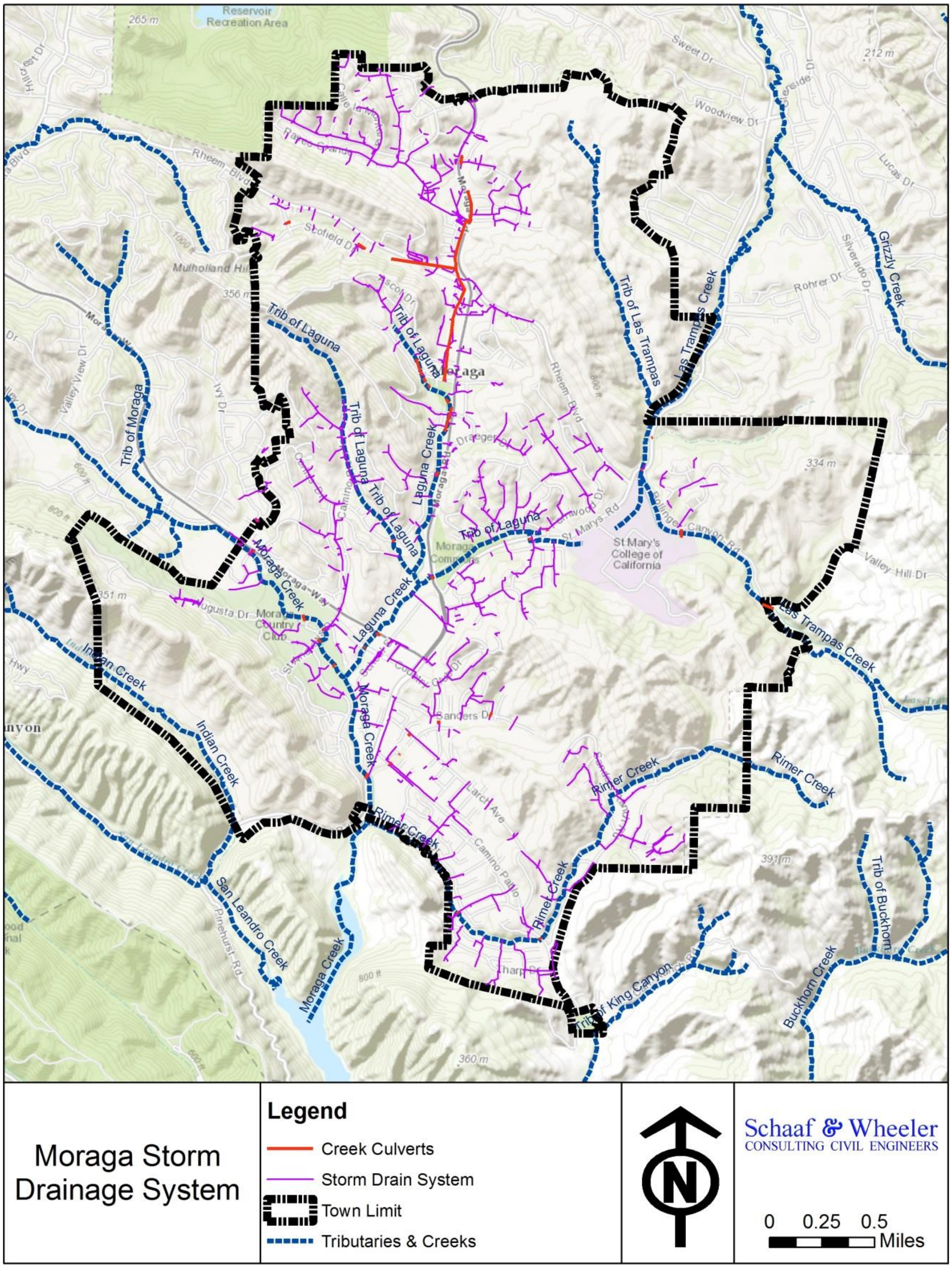

Figure 1-1: Moraga Drainage

1.5. History of High Water Events Within Moraga

Heavy rainfalls occurring during the winter months have produced high water situations in Moraga. Historical flooding information can be valuable in highlighting areas of recurring problems and prioritizing future improvements. Areas with known problems have been identified by Schaaf & Wheeler (S&W) and the Town employees which are detailed in Chapter 2.

Flooding locations during a 100-year storm event were identified within the *2009 FEMA Flood Insurance Study* (FIS) for Contra Costa County. Zones A and AE are 100-year floodplains. The largest contributors to 100-year flooding in Moraga are flows from Laguna Creek at the Hacienda Pavilion and Las Trampas Creek near Saint Mary's College, where an old dam existed. Figure 1-3 shows the FEMA flood zones in Moraga. Detailed mapping is available on the FEMA web site (www.msc.fema.gov).

Figure 1-2: High Flow Events in Moraga – Hacienda Culvert (top left) Missouri Riser (top right) St Mary's Road Culvert with Sediment (bottom left) Hacienda Culvert Headwall (bottom right)

1.6. Recent Flood Protection Measures

The Town of Moraga has been working to alleviate inadequacies in the existing storm drain system by making system improvements. Some recent activity has focused on:

1. Planning and design of the Hacienda Pavilion creek daylighting project,

2. Design and construction of new headwall at Hacienda Pavilion,
3. Patch repair of 96-inch Rheem Shopping Center culvert,
4. Annual maintenance of catch basins, and
5. *2008 Storm Drain Needs Study* that documented problem areas within the creek culvert system and inspection of corregated metal pipes that were 36-inch or greater in diameter

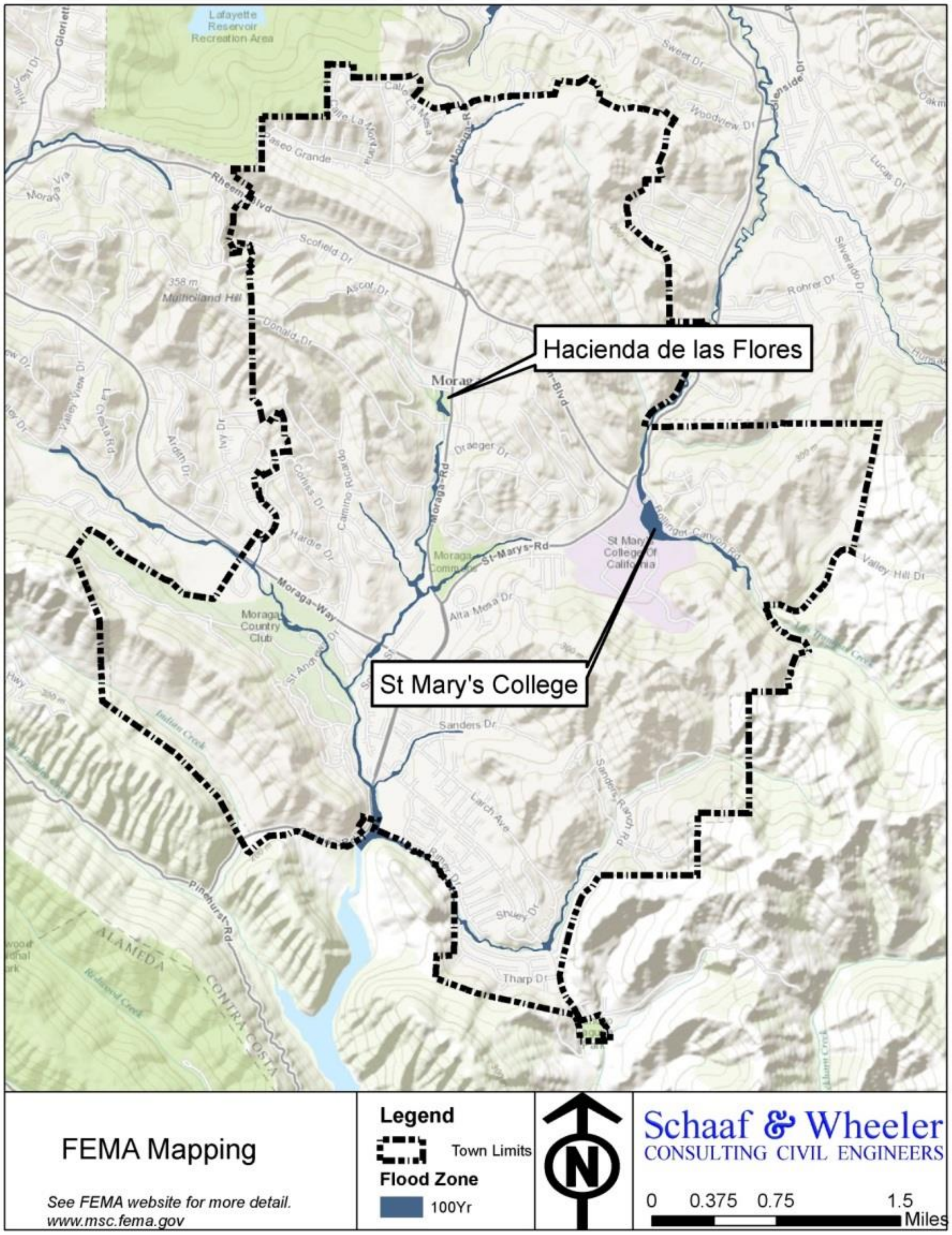

Figure 1-3: FEMA Flood Zones in Moraga

1.7. Master Plan Process

The basic process to complete this master plan document is to analyze the current Moraga storm drain system performance along with Town operations and procedures to determine the improvement required to provide a 10-year level of service within the pipes and 100-year flood protection within the creeks. Several tasks were completed to reach this goal. The following list is a summary of steps taken:

1. Development of a geographical information system (GIS) storm drain system from Town paper maps. The GIS data was used to create the hydraulic model. Network features include: manhole invert and rim elevations, pipe length and diameter, and watershed runoff characteristics.
2. Field verification by consultant and Town staff.
3. Condition assessment of approximately 80 drainage features.
4. Video inspection of over 12,000 linear feet of pipe.
5. Field investigation of 35 creek culverts.
6. Storm drainage analysis methodologies and criterion were established with Town staff.
7. Investigation of the Town's easements and/or dedications and recommendations for future investigations into the acceptance of easements.
8. A hydrologic and hydraulic analysis of the existing storm drain facilities throughout Moraga was performed for a 10-year storm event using Contra Costa County methodology. System deficiencies on Town-owned facilities are categorized in terms of the risk to public safety and infrastructure.
9. Hydraulic modeling of creek culverts using 100-year FEMA published hydrologic flows. System deficiencies are categorized in terms of the risk to public safety and infrastructure.
10. Identification of projects that will improve storm drain and creek culvert system performance. Some private system upgrades are also identified.
11. A prioritized Capital Improvement Program (CIP) is outlined.
12. Projected capital improvement costs are summarized.

1.8. References

- General Construction Permit. State Water Resources Control Board: Division of Water Quality. (Order 2009-0009-DWQ as amended by 2010-0014-DWQ). (2010).
- Municipal Regional Stormwater NPDES Permit No. CAS612008. California Regional Water Quality Control Board: San Francisco Bay Region. (Order R2-2009-0074). (2009).
- HEC-HMS Guidance for the Contra Costa County Flood Control & Water Conservation District Unit Hydrograph Method. Contra Costa County Flood Control & Water Conservation District. (2011).

Chapter 2. Data

2.1. Overview

Schaaf & Wheeler (S&W) reviewed and utilized readily available land use, topographic, geographical, and storm drain system data within the Moraga Storm Drain Master Plan Area (study area). Available data often had missing or incorrect information. Efforts were made to improve and add to the collective data. Where necessary, assumptions and engineering judgment were used to complete remaining data gaps. This chapter summarizes the findings and data acquired as part of the Moraga Storm Drain Master Plan (SDMP). Data limitations, assumptions, and impacts are also summarized herein.

2.2. Data Sources

2.2.1. Topography and Aerial Imagery

All project data and results are in vertical datum NAVD88 (feet) and State Plane (California Zone III) coordinate system. Contra Costa County DEM LiDAR topography data (NAVD) with half foot accuracy (plus or minus 0.5 foot) is utilized for ground surface information. Aerial Imagery is the ArcGIS High Resolution Basemap which is 30cm (1-foot) satellite imagery taken in November 2010 and compiled by ESRI.

2.2.2. GIS Data

The Town provided hard copy maps from 1995 to the Schaaf & Wheeler team for use on this project. These maps were the most current information that the Town used to identify the location of storm drain systems. The maps contained street, pipe, and node (pipe connections such as catch basins, manholes, inlets, outfalls) details. S&W trained Town staff to digitize the paper maps into GIS shapefiles for storm drain pipes and storm drain nodes. Existing zoning and parcel data was provided by the Town's planning department. The created shapefiles for the storm drain pipes and nodes were missing a significant amount of information critical to accurately model the storm drain system. Some routinely encountered examples include:

- missing pipes, manholes, inlets, and outfalls;
- missing pipe sizes;
- rim and/or invert elevations unknown;
- node type unknown.

The inadequacies of the data and steps taken to complete the data set to a master planning level of accuracy are detailed in the Data Quality and Data Assumptions sections of this chapter.

2.2.3. Historical Data

In 2005, the downstream retaining wall on the existing 8-ft diameter culvert conveying Laguna Creek through the Hacienda de Las Flores property fell into the creek during a large storm event. The outfall from the culvert was causing scouring problems to the downstream and broken pieces of concrete were left in the stream. In 2013, a construction project repaired the scoured channel with 1-ton rock slope protection at the outlet face and repairs were also made to the inlet of the 8-ft diameter culvert. An engineering consultant of the Town, WRECO, is currently studying the feasibility of daylighting portions of Laguna Creek near the Hacienda de Las Flores Park. The Town is currently reviewing alternatives to alleviate frequent flooding in this area.

2.2.4. As-Builts

As-Builts and improvement plans (when available) were provided by the Town for developments in Moraga to verify the Town provided GIS data, and for Schaaf & Wheeler to fill in data gaps.

2.2.5. Condition Assessment

V&A, Schaaf & Wheeler's condition assessment sub-consultant, spent approximately two weeks in the field inspecting the drainage network. Corrosion, debris and sedimentation buildup, and system damage were noted. The findings are detailed in Appendix A. V&A looked at a range of pipe materials and sizes at various locations in order to obtain a representative sample of issues occurring within the Town's drainage facilities. It was cost prohibitive to inspect the entire system. Town staff prioritized inspection locations based on known issues and concerns, with an emphasis on corrugated metal pipes (CMP) greater than 24-inches in diameter.

V&A also filled data gaps and verified key locations within the system, measured missing pipe diameters and invert (bottom) depths and documented the condition of storm drain facilities. Collecting accurate pipe diameters was the highest priority in field measurements. Storm drain systems are designed to surcharge (pressure flow), so invert elevation becomes less critical than pipe diameter because the system's hydraulic grade line (HGL) is not governed by open channel flow dynamics.

2.3. Land Use Data and Runoff Characteristics

The Town currently does not keep GIS data that depicts existing or future land use. Existing land use was developed by S&W using zoning information and aerial imagery. In some cases, the existing land use designation was edited if the zoning designation did not correspond to the land use shown in the aerial photography. Future land use was developed using zoning information, development plans, and plans for large developments such as the Moraga Center. Moraga is primarily residential with two small commercial sectors, one at Rheem Boulevard and Moraga Road and the other at Moraga Road and Canyon Road. The various land use codes and descriptions utilized in the GIS database are summarized in Table 2-1. Figure 2-1 and Figure 2-2 show existing and future land uses within the Town.

Table 2-1: Land Use Codes and Descriptions

Land Use	Description	Land	Description
1-DUA	Residential – 1 dwelling unit/acre	LC	Limited Commercial
2-DUA	Residential – 2 dwelling unit/acre	SO	Office
3-DUA	Residential – 3 dwelling unit/acre	ST	Street
6-DUA	Residential – 6 dwelling unit/acre	Study	Vacant
CC	Community Commercial	OSM	Open Space
C	College	Vacant	Undeveloped land

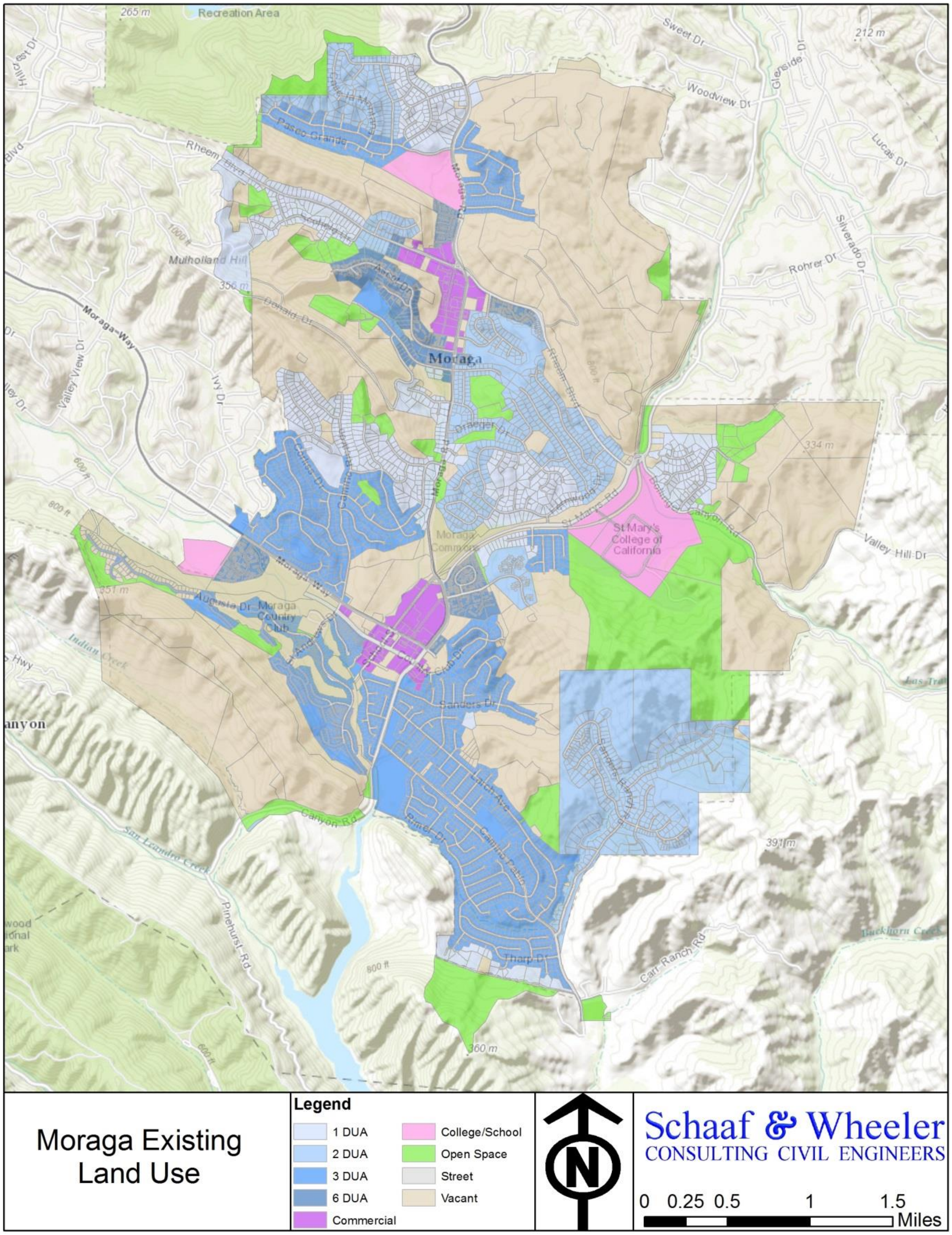

Figure 2-1: Existing Land Use

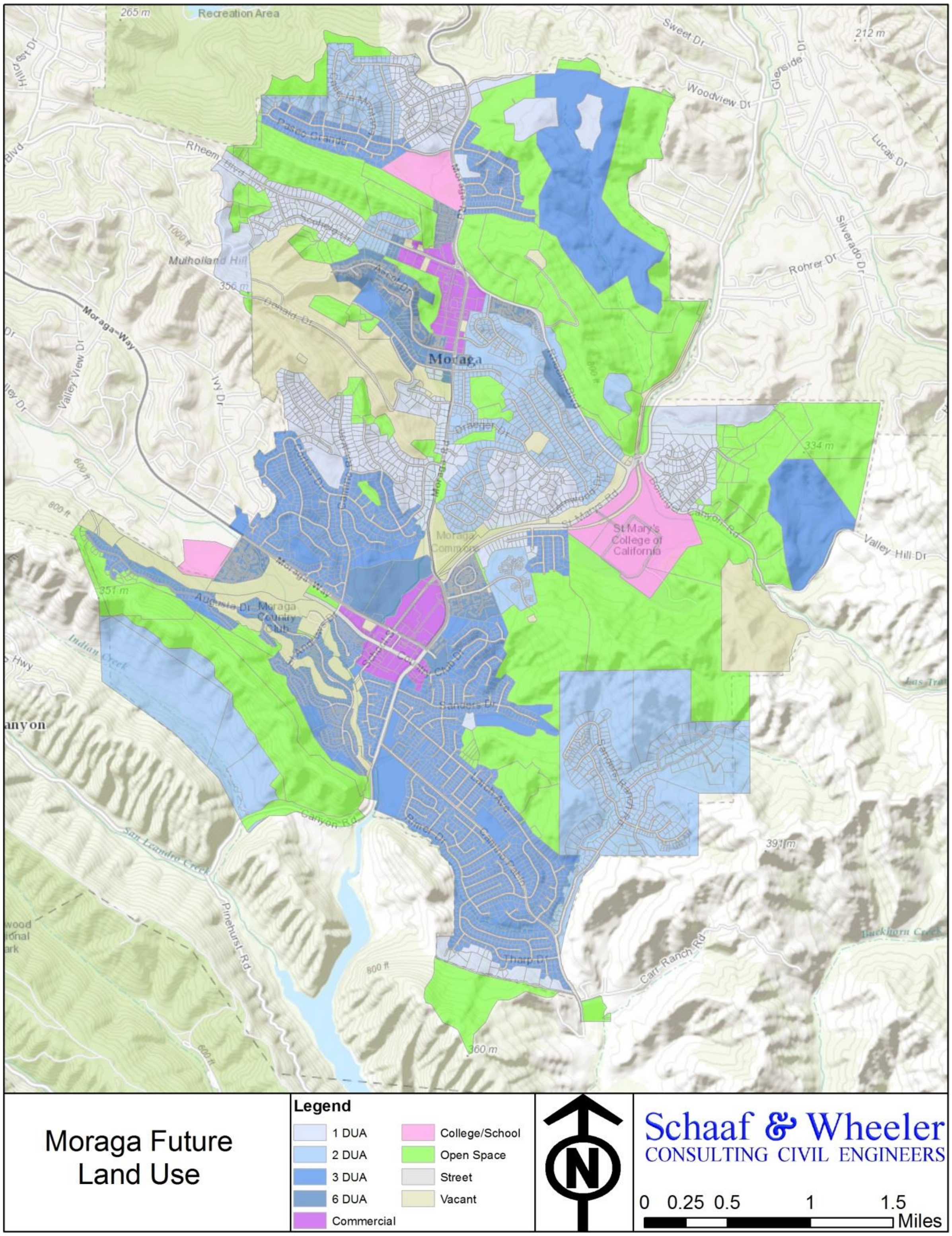

Figure 2-2: Future Land Use

2.3.1. Runoff Characteristics

Rainfall runoff is determined by land use and infiltration rates. The County methodology, also described in Chapter 3, is used for surface runoff calculations. Infiltration rates were assigned to various land uses based on values published in the *Verification of District Standards*, 2011. Because infiltration rates are inclusive of percent impervious, no calculations were made on percent impervious.

Table 2-2: County Infiltration Rates (Table 8 from *Verification of District Standards,* 2011)

Zoning	Lot Size		HYDRO6 Low Value	HYDRO 6 Average Value	HYDRO 6 High Value
	Square Feet (net)	DU/Acre (gross)	Infiltration Rate (Inches/Hour)		
Open			0.170	0.175	0.180
R-40	40000	0.82	0.140	0.150	0.160
R-20	20000	1.63	0.110	0.125	0.140
R-10	10000	3.27	0.080	0.095	0.110
R-6	6000	5.45	0.050	0.065	0.080
Multi Residential		10.00	0.040	0.050	0.060
Industrial			0.030	0.045	0.060
Commercial			0.020	0.035	0.050

2.4. Data Quality

The quality and accuracy of the data obtained from the Town for use in developing the Moraga SDMP varies significantly. The Town's existing GIS is generally spatially accurate but some attribute data is missing and/or un-sourced. In many cases, as-built plans could not be located, so S&W field verified where it was necessary for modeling efforts.

The Town has over 200,000 linear feet of pipe (1,700 links) and approximately 2,000 nodes (manholes and inlets) that are now mapped in GIS. It is estimated that this is more than 85% of the total system based on aerial maps of developments throughout the Town. Forty-percent of the pipes are missing diameter information and almost all of the nodes were missing invert information. The node depth data was gathered from various sources (Town staff, V&A, Presidio Inc., S&W) and combined using LiDAR (digital elevation) ground surface data from the County. The node depths were subtracted from the LiDAR surface in order to transfer the invert elevations to NAVD88. Field inspections and assumptions were made to assign missing pipe diameters and node depths.

2.4.1. Modeled Data Assumptions

For this study S&W compared the original GIS data provided by the Town with field data collected by Town staff, V&A, and site inspections performed by S&W. Data corrections or additions were manually entered into GIS with data source noted. Missing pipe diameters were typically assigned the same diameter as the pipe upstream, unless there was a valid reason for assuming a larger diameter. In cases where there were no surrounding pipe diameters known, a diameter of 18-inches was used. This SDMP looks at only the storm drain system that is 18-inches or greater. If a pipe with an assumed diameter was found to be undersized during capacity analysis, field verification was performed if possible, otherwise, the capital improvement project first recommends site investigation to verify pipe diameter.

Rim elevations were assigned to every node using the previously described LiDAR data. For nodes with invert and rim elevations, the depth to invert was calculated and subtracted from the newly assigned rim elevation. The remaining inverts were assigned based on applying the field measured depth, interpolating between known upstream and downstream nodes, or assuming a 5 foot depth. Node inverts were interpolated using the interpolation tool in the MIKE URBAN (MU) model between points of known invert elevation. Node invert elevations were assumed on a case by case basis when the interpolation tool could not be applied.

Chapter 3. Storm Drain System Methodology

3.1. Overview

The criteria used to evaluate storm drain system performance must be technically sound yet simple to understand and apply. Ideally, the methodology used to analyze system performance will continue to be used for future infrastructure design as well. The Town of Moraga utilizes the Contra Costa County (County) hydrology standards that can be found online at http://www.cccounty.us/2455/Hydrology-Standards. The County's method is being used along with MIKE URBAN (MU) by the Danish Hydraulic Institute (DHI) storm drain modeling software to determine system performance and beneficial improvements. Physical parameters used in the model are based on the Town's GIS data and other information detailed in Chapter 2 - Data. Storm drain evaluation criteria have been developed with input from the Town staff.

3.2. Evaluation Criteria

The methodology described in the *HEC-HMS Guidance for the Contra Costa County Flood Control & Water Conservation District Unit Hydrograph Method* (County Drainage Manual) was used to estimate storm runoff in Moraga. The County Drainage Manual was developed in 2011 to provide consistent design and evaluation criteria for storm drainage throughout Contra Costa County. The County method uses the soil moisture accounting methodology with a specified S-graph. This methodology is not inherent to the MU model, so a HEC-HMS model was developed for several of the storm drain catchments to calibrate the hydrologic procedures in MU to match the County's methodology using HEC-HMS. Section 3.6.3 discusses how the loss rates were modified in MU to match results in HEC-HMS.

The standard storm duration used in the County Drainage Manual for rainfall simulation is 3-hours. The precipitation pattern can be found on page 12 of the County Drainage Manual. It should be noted that the infiltration rates do not change for different durations and storm frequencies. In some cases, it has been found that the County method overestimates flows. This is based on comparing the flows per square mile (cfs/sq.mi.) to flows reported in the Flood Insurance Study (FIS) report by FEMA. Ranges of 500-900 cfs/sq.mi are calculated 10-year discharges using the County methodology as compared to ranges of 200-450 cfs/sq.mi for FEMA published 10-year flows.

This master plan effort includes modeling the hydrology for the 10-year storm event, which is used as the design event for the storm drain system. Based on conversations with Town Staff, the 10-year level-of-service standard is consistent with the County and neighboring municipalities. For the purposes of this report, improvements are recommended that reduce the hydraulic grade to no higher than 0.5 feet above the gutter elevation at any node such that the maximum hydraulic grade is the top of curb elevation. This will minimize the risk to private property and increase public safety as the storm drain overflows are contained within the streets by the curb.

3.3. Modeling Software

The MU software with MOUSE solver was selected to model the Moraga storm drain system because it is atested and reliable software with a GIS interface and is widely used for storm drain master planning. MU is a package of software programs designed by the DHI for the analysis, design, and management of urban drainage systems, including storm water sewers and sanitary sewers. The MU model works within ArcMap GIS (the GIS software used by Town staff) and can simulate runoff, open channel flow, pipe flow, water quality, and sediment transport. The program was chosen to model the Moraga storm drain system because of its capabilities to connect overland flow to a storm drain system consisting of pipes and channels. The Moraga storm drain system is modeled as one drainage region based on outlet points to creeks and ditches.

3.3.1. Operation

Two separate calculations are performed by MU for the Moraga models: a runoff calculation estimating the amount of water entering the storm drain system during a design rainfall event, and the network flow calculation which replicates how the storm drain system will convey flows to outlet locations. Flows resulting from the runoff calculation are used as inflows for the subsequent network flow calculation. The MU runoff model offers a choice of infiltration methods. The Moraga storm drain models use the Natural Resources Conservation Service (NRCS) dimensionless hydrograph method to calculate surface runoff. This method was formally known as the "SCS Method." This method does not directly produce the same results as HEC-HMS, which is the preferred hydrology model of the County. S&W performed a calibration of the runoff parameters in MU to reproduce the HEC-HMS results consistent with the County methodology. It was found that increasing the initial storage in the MU model to 0.5 inches and increasing the infiltration rates by 20% matched the runoff peaks with the Contra Costa HEC-HMS methodology (see Section 3.6.3). A simulation can be started at any point during the chosen design storm to assess surface runoff for any period of the design storm, with computations made based on a user-specified time step. The runoff time steps were chosen to be at 5-minute intervals.

The MU network flow model offers a choice of three flow description approximations distinguished by the set of forces each takes into account:

1. Steady,
2. Dynamic Wave, and
3. Kinematic Wave

The Moraga storm drain models use the most comprehensive flow description, Dynamic Wave, which incorporates the effects of gravitational, friction, pressure gradient and inertial forces. Because it accounts for all major forces affecting flow conditions, this equation allows the model to accurately simulate fast transients and backwater profiles. The simulation of overflows at a node is accommodated by the insertion of an artificial "basin" above the node which will store water when the water level rises above the ground level. The surface area of the "basin" gradually increases (up to a maximum of 1000 times the node surface area) with rising water levels at the node, replicating the effects of storm drain overflows.

Water stored in the "basin" begins to reenter the system when the outflow from the node becomes greater than the inflow. The pipe flow simulation can be executed using either a constant or variable time step, and can be run for any portion of the time interval specified by the input rainfall time series and corresponding calculated runoff hydrograph.

3.3.2. Input and Output

MU surface runoff calculations require two types of input data:

- boundary data and
- urban catchment data.

Boundary data for the run-off computation consists of an input rainfall time series representing the design storm event for the model and a constant water surface elevation at the outlet nodes representing the 100-year water surface elevation in the creeks.

Urban catchment data includes the pipe network and boundaries of each drainage catchment, along with relevant physical and hydrologic parameters including surface area and parameters used to calculate basin lag time. Drainage catchments for the study area are shown in Figure 3-1.

Output from the pipe flow computation includes the calculated water level at each node, discharges, water level in network branches, discharge in network branches, velocity in network branches, water volume in the system, and time step data. Output is viewed using GIS, MU, or the MIKE-VIEW program. Results can be displayed in plan-view or as a profile for a selected network section; and can be viewed as a temporal animation or at maximum or minimum values. Additional outputs which can be derived from MU pipe flow results using GIS include: water depth, overflow level, pressure in closed conduits, percentage pipe filling, and the flow calculated for each link.

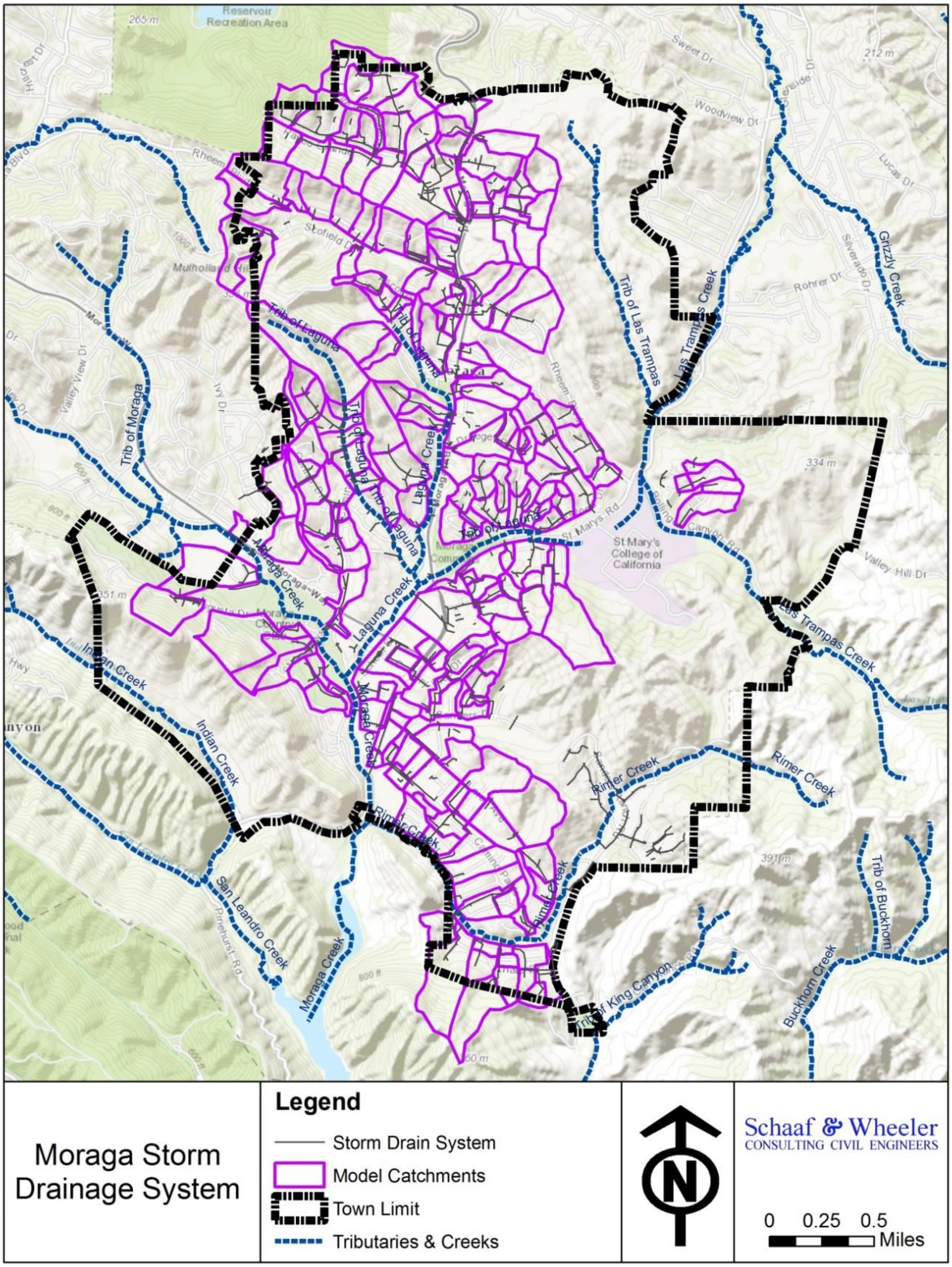

Figure 3-1: Moraga Storm Drain System Catchments

3.4. Hydrology Calculations

Methods used in this master plan to estimate peak storm drain flow rates and volumes require the input of precipitation data. Since it is impossible to anticipate the impact of every conceivable storm, precipitation frequency analyses are often used to design facilities that control storm runoff. A common practice is to construct a design storm, which is a rainfall pattern used in hydrologic models to estimate surface runoff. A design storm is used in lieu of a single historic storm event to ensure that local rainfall statistics (i.e. depth, duration and frequency) are preserved. When combined with regional specific data for land use and loss rates, the model should produce runoff estimates that are consistent with frequency analyses of gauged stream-flow in the Contra Costa County area. In other words, the ten-year design storm pattern used for MU modeling creates results consistent with a ten-year storm runoff event.

Precipitation frequency analyses are based on concepts of probability and statistics. Engineers generally assume that frequency (probability) of a rainfall event is coincident with frequency of direct storm water runoff, although runoff is determined by a number of factors (particularly land use conditions in the basin) in addition to the precipitation event. The County's 3-hour rainfall pattern was verified using the US Army Corps of Engineers' *Standard Project Criteria for General and Local Storms, Sacramento-San Joaquin Valley* dated April 1971. The County compared their 3-hour pattern to the USACE pattern and believes that it matches very closely and the comparison verifies the distribution of the rainfall pattern. Since County 3-hour storm pattern has been adjusted to preserve local statistics, there is increased confidence in this correspondence between the frequency of the rainfall and the frequency of the runoff.

3.4.1. Mean Annual Precipitation

Mean Annual Precipitation (MAP) information was taken from the California Isohyet GIS layer developed by Oregon State University and the NRCS because the data is electronic and more current than the data provided by the County. The mean annual precipitation values match well with the Isohyet map provided by the County and have slightly higher values in the mountainous regions. The isohyet map indicates a MAP for the Town of Moraga at 28 inches per year.

3.4.2. Rainfall Depth

The rainfall depth was taken from the Intensity Frequency Depth curves for 10-year Duration – Frequency – Depth Curves provided in the county Hydrology Standards website. The depth calculated was then compared to the NOAA Atlas 14 precipitation frequency estimates to ensure consistency. Both methods produced 1.9 inches of rain for the 3-hour, 10-year event.

3.4.3. Rainfall Pattern

The rainfall distribution pattern for the Moraga Storm Drain Master Plan was obtained from the County's HEC-HMS Guidelines located on the web at http://ca-contracostacounty2.civicplus.com/2455/Hydrology-Standards.

The County's rainfall pattern is distributed in 15-minute time increments with a fraction of the total rainfall apportioned to each 15-minute increment. The total depth of each pattern is based on the mean annual precipitation taken from the California Isohyet GIS layer from the NRCS.

The County Drainage Manual provides a table with the total rainfall depth for each MAP and the storm frequency rainfall pattern for a 3-hour, 10-year storm event. Table 3-1 and Figure 3-2 show the corresponding pattern in tabular and chart format.

Table 3-1: 3-hour Rainfall Pattern

Time (hrs.)	Fraction	Inches
0.25	3.0	0.06
0.50	2.0	0.04
0.75	5.0	0.10
1.00	2.8	0.05
1.25	8.8	0.17
1.50	10.2	0.19
1.75	5.5	0.10
2.00	7.0	0.13
2.25	10.5	0.20
2.50	11.0	0.21
2.75	27.7	0.53
3.00	6.5	0.12

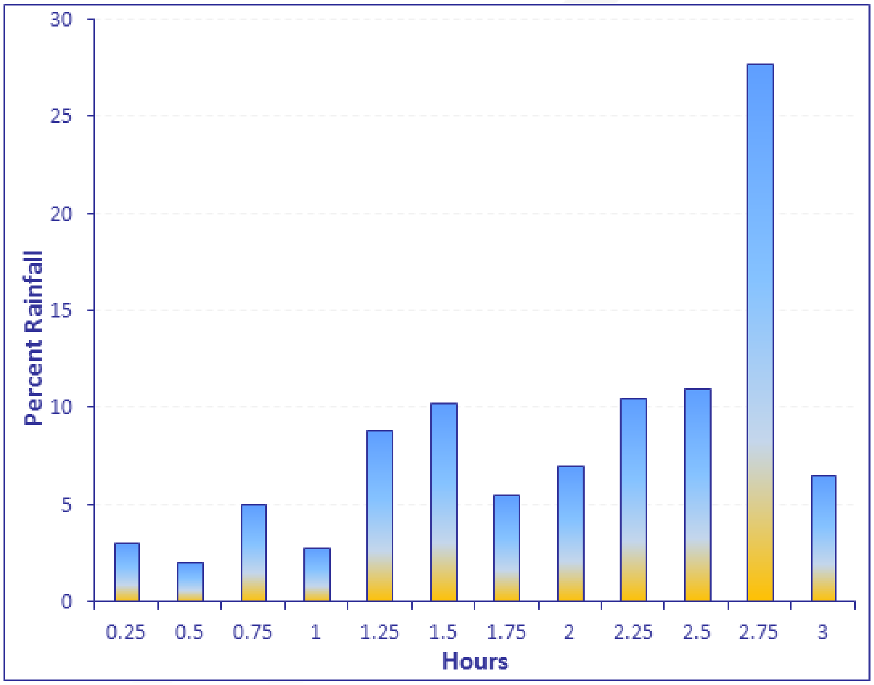

Figure 3-2: Contra Costa County 3-Hour Storm Pattern

3.5. Catchment Data

Moraga is divided into drainage areas, called catchments. The catchment delineations were completed by S&W and rely heavily on engineering judgment and experience using contours, lot lines, storm drainage system, and aerial imagery. Urban catchment data includes the boundaries of each drainage catchment, along with relevant physical and hydrologic parameters including surface area, land use characteristics, and parameters used to calculate basin lag times.

3.5.1. Unit Hydrograph

A unit hydrograph is a numerical representation of the time response of catchment runoff caused by one inch of excess rainfall applied uniformly over a unit of time. Many different techniques are available to estimate unit hydrographs. The NRCS-dimensionless unit hydrograph is used in the Moraga storm drain models as it was the closest to matching the County's specified S-graph. Direct runoff is estimated by subtracting soil infiltration and other losses from the rate of rainfall. Uniform loss, which accounts for constant infiltration of rainfall into the soil, is a function of both soil type and ground cover (i.e. vegetation type or land use).

3.5.2. Basin Losses

As mentioned previously, the unit hydrograph methodology was used to determine basin runoff. This methodology relies on the use of initial and constant losses to characterize basin infiltration and runoff potential. Losses are based on a combination of infiltration rates by land use and initial loss rates. An initial loss of 0.5-inches was used for all land uses. This is greater than the 0.25-inches recommended in the County Drainage Manual to ensure that the MU results matched those of the HMS results as previously described in Section 3.2. The constant losses are based on the average rates in the County HEC-HMS method increased by 20% to match HMS results. Figure 3-3 shows how the hydrology in MU results match those from HMS and Table 3-2 lists the losses associated with the calibrated MU model. When sizing storm drain pipes, peak discharge is more important than volume.

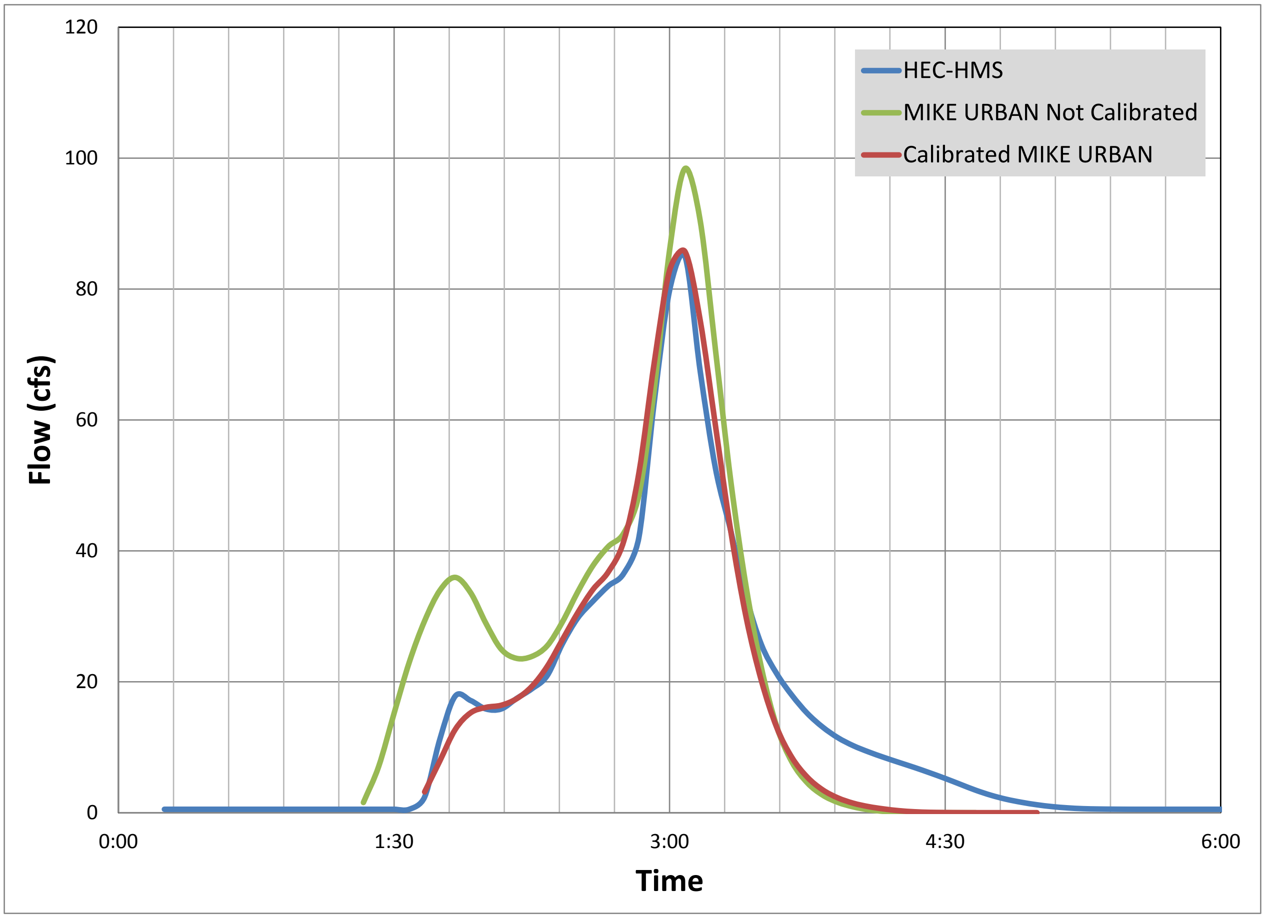

Figure 3-3: County Hydrology Method Calibrated in MIKE URBAN to match HEC-HMS

Table 3-2: Land Use Codes and Descriptions

Land Use Code	Description	County Constant Loss (in/hr)	Calibrated MU Constant Loss (in/hr)
OS	Open Space	0.175	0.210
College	School	0.163	0.196
1-DUA	1 dwelling unit per acre	0.15	0.180
2-DUA	2 dwelling unit per acre	0.125	0.150
3-DUA	3 dwelling unit per acre	0.095	0.114
6-DUA	6 dwelling unit per acre	0.065	0.078
SO, CC, LC	Commercial	0.035	0.042
ST	Streets	0	0
OSM DT	Open Space	0.175	0.210
Vacant	Undeveloped Land	0.175	0.210

3.5.3. Basin Lag

The County Drainage Manual recommends the US Army Corps of Engineers lag equation expressed by the following:

$$T_{lag} = 24\ x\ N\ x\ \left(\frac{L\ x\ L_c}{S^{.5}}\right)^{0.38}$$

Where T_{lag} = Elapsed time from the beginning of an assumed continuous series of unit effective rainfalls over and area to the instant at which the rate of the resulting run-off at the area concentration point equals 50 percent of the maximum (ultimate) rate of the resulting run-off at that point. This therefore corresponds to the Time = 100% and volume = 50%. The S-curve percent time goes to 840% of Tlag.

L = length of the main drainage path (miles)

L_{ca} = length along that drainage path from a point opposite to the centroid of the watershed to the outlet point (miles)

S = overall slope of the main watercourse (feet/mile)

N = weighted watershed Manning's coefficient (dimensionless)

This equation uses basin length, shape, slope and land use to estimate lag. The County's 2006 LiDAR data was used to estimate basin flow paths and slopes. GIS was used to determine basin centroids and centroid lengths. It should be noted that the basin roughness factor (N) is not the same as Manning's roughness coefficient (n). A basin roughness of 0.04 was used for Moraga based on Figure 1 from the County's Hydrograph Request Form.

3.6. Model Calculations

MU pipe flow calculations require network data, operational data, and boundary data as input. Network data consists of the pipe network elements including nodes (manholes, outlets, and storage nodes) and links (pipes, culverts, and open channels). Detailed analyses of peak storm drain discharge are performed by the MU program, which also determines the flow condition in each drainage system element. The MU technical manual should be referenced for a more detailed description. Pipes with diameters less than 18-inches were not included in this modeling effort. The majority of these pipes with smaller diameters fall within private property.

3.6.1. Links

Parameters required to describe links include the name of upstream and downstream nodes, shape and dimensions, material or roughness, and upstream and downstream inverts. Structural system elements including gates and weirs are all modeled as functional relationships connecting two nodes in the system, or associated with one node in the case of free flow out of the system. Operational data consists of parameters which describe how these elements function in the network. Boundary data for the pipe flow computation can include any external loading, inflow discharges, water levels at interaction points with receiving waters, as well as the results of a run-off calculation.

Pipes are modeled as one-dimensional closed conduit links which connect two nodes in the models. The conduit link is described by a constant cross-section along its length, constant bottom slope, and straight alignment. Unsteady flow in closed conduits is calculated using conservation of continuity and momentum equations, distinguishing between pipes flowing partially full (free surface flow), and those flowing full (pressurized flow). Most pipes within the Moraga model are modeled as reinforced concrete pipe (RCP) with a Manning's '*n*' of 0.013 or corrugated metal pipe (CMP) with an 'n' of 0.025.

3.6.2. Junction Losses

Parameters required to describe nodes include *x* and *y* coordinates of the node, a unique name, node type (junction, outlet or basin), depth and invert levels, and water levels at outlets. Hydraulic losses at junctions (manholes, inlets, intersections) can be significant in pressurized drainage systems. Losses can vary due to construction methods, condition, and shape. S&W performed a sensitivity analysis of the loss coefficients used in MU to determine the most realistic model parameters. The MU Weighted Inlet Energy Method is used for this study.

3.6.3. Outlet Boundary Conditions

Pipe network outlets can be modeled with either a free outfall or a water surface elevation (fixed or variable with time) which captures backwater effects due to receiving water levels. The modeled system contains over 50 outfalls with very limited information. The water surface elevation at most outlets were set to free outfalls, with the exception of those outfalls to major creeks in which the 100-year water surface elevation was used as the boundary condition. The 100-year water surface elevations were calculated as part of the creek culvert system analysis using HEC-RAS.

Chapter 4. Creek Culvert System Methodology

4.1. Overview

The criteria used to evaluate the creek culvert system performance were based on the *2008 Storm Drain Needs Assessment* (2008 Study) that was developed for the Town by Stormwater Consulting Engineers. The Creek culverts were assessed for the 100-year design flows estimated by FEMA in the FIS report from 2009 for the County. Eleven creek and tributary systems with 35 culverts were assessed for capacity to convey the 100-year FEMA flows. This effort included four additional tributaries and seven additional culverts to the 2008 Study.

4.2. Modeling Software

HEC-RAS was selected as it is the modeling software accepted by FEMA in development of floodplains and it was anticipated that FEMA would provide HEC-RAS models of the mapped creek systems. Unfortunately, FEMA does not have electronic models, but rather scanned copies of micro fiche input files for HEC2 (predecessor to HEC-RAS). Rather than trying to recreate HEC2 models, S&W utilized GeoRAS to develop new HEC-RAS models for the creek systems throughout Moraga.

4.3. Field Investigations

S&W spent two days in the field to collect culvert measurements for all 35 culverts and to estimate channel roughness (Manning's 'n'). Pictures were taken and dimensions documented. Field sheets and pictures are included in Appendix B.

4.4. Hydrology Calculations

FEMA published 100-year flows were used, where available. For culverts in intermediate locations, pro-rated flows were calculated based on the average flow per square mile in that creek system. On average, the 100-year flows in Moraga are around 550 cfs/square mile. This is in-line with statistical data for the nearby USGS gage on San Ramon Creek. There are no USGS gages within Moraga.

4.5. Hydraulic Calculations

HEC-RAS models were developed and run in steady state. In the 2008 Study, culverts were assessed for inlet capacity and did not consider outlet control. HEC-RAS has the capability to analyze both inlet and outlet control for culvert capacity.

4.5.1. Culvert Routines

HEC-RAS utilizes the Federal Highway Administration's (FHWA) standard equations for culvert hydraulic computations. The analysis of flow in culverts is complicated. To simplify, there are two types of controlling factors in the capacity of the culvert: inlet and outlet. Inlet control occurs when the carrying capacity of the culvert entrance is less than the flow capacity of the culvert barrel. Outlet control occurs when the flow capacity of the culvert barrel is greater than the downstream conditions.

4.5.2. Flow Regime

Models were run steady state with normal depth boundary conditions except for tributaries into larger creeks where the downstream boundary condition was set to the 100-year water surface elevation in the main creek. The flow regimes were set to mixed flow as many of the models had Froude numbers close to 1.0.

4.6. Culvert Properties

HEC-RAS gives the user the ability to enter detailed information about each culvert. Roadway elevations were estimated based on LiDAR and roadway widths were measured where possible in the field and estimated in Google Earth when measurements were unsafe. HEC-RAS uses the upstream and downstream cross sections to estimate the culvert cross section. In some cases, GeoRAS cross sections were updated to match measurements made in the field.

4.6.1. Losses

Exit losses were set to 1 as recommended in the *HEC-RAS User's Manual*. Entrance losses were set to 0.5, which is conservatively high to account for vegetation and meandering channels.

4.6.2. Channel Roughness

Manning's 'n' is a quantification of channel roughness. A value of 1.0 is used for highly vegetated channels with many obstructions such as trees and boulders. A clean channel has a roughness of around 0.025. Many of the creeks and tributaries in Moraga are overgrown with vegetation. To account for the possibility of unmaintained channels, a manning's roughness from 0.04 to 0.08 was used for the main channel. The roughness of the banks and overflow was set to 0.1 to account for overflows that may pass through residential neighborhoods.

4.6.3. Expansion and Contraction Coefficients

Upstream and downstream cross sections to culverts were given contraction coefficients of 0.3 and expansion coefficients of 0.5.

4.6.4. Culvert Encroachments

Ineffective flow areas were added to upstream and downstream cross sections of culverts to account for contraction and expansion of flows. Encroachments on the upstream cross section were set to 1:1 for contraction while downstream encroachments were set to 4:1 for expansion.

Chapter 5. Evaluation of Storm Drain System

5.1. Overview

The performance analysis of Moraga's storm drain collection system forms the essential core of this master plan. This chapter describes major storm drain facilities and known drainage issues. Areas recommended for system improvements are also identified and prioritized herein. This chapter presents the 10-year predicted storm drain overflow depths for the existing land use condition and recommends projects that alleviate or minimize storm drain overflows based on the 10-year standard. Future land use conditions have been applied to the updated system to determine if any additional projects would alleviate impacts from future land use changes due to development.

This chapter also discusses improvement projects based on V&A's condition assessment, Presidio Inc.'s televised inspection under 2015 Pavement Reconstruction Project, and recurring issues that were identified by the Town staff.

5.2. Evaluation of the Storm Drain Capacity

The collection system has been analyzed for existing land use condition to determine its performance during the design 10-year storm. Areas of storm drain overflows are identified. Improvements are recommended to improve system performance to the 10-year capacity. Future land use was modeled and any additional improvements are recommended to the improvements to improve the existing condition. It is impossible to entirely remove predicted storm drain overflows throughout the project area, either due to local topography (for example, at minor 'bathtub' areas) or storm drain overlows that are caused by a creek. The majority of model-predicted storm drain overflows can be mitigated with the capital improvements proposed herein.

5.2.1. Design Criteria

The capacity of the storm drain system was analyzed under the 10-year storm event which has a 10% chance of occurring every year. The Town of Moraga does not have a published drainage design criteria. After discussions with the Town, it was decided that the drainage design criteria to develop capital improvement projects would be to contain the 10-year storm event within the streets. Since the curbs are typically 6-inches high, capital improvement projects are identified in locations where storm drain overflows exceed 6-inches in depth.

5.3. Prioritizing Deficiencies and Needed Improvements

The storm drain system in Moraga (both Town-owned and private elements) conveys the majority of the runoff towards the major creeks through storm drain systems consisting of pipe and ditches. This Chapter focuses on the pipe system and Chapter 6 focuses on the creek culverts. It should be noted that site-specific drainage characteristics (i.e. individual parcels) have not been analyzed. Future refinement of the model could more precisely account for these site-specific drainage characteristics and represent the local drainage conditions more accurately.

Recommended master plan improvements are described in the following discussion. In some locations, the hydraulic grade line (HGL) predicted by the model at individual nodes in the system may be greater than actual water surface elevation during a storm event. This is due to limitations and assumptions inherent in the modeling software. Locations for recommended system improvements are based on the results of this complete process. The recommended improvements were then prioritized based on the results of the above process, combined with consideration of the anticipated severity of storm drain overflows at each location and the benefit/cost relationship of proposed improvements. The following color code is used to highlight project prioritization:

Improvement Priority	Priority Description
High Priority	Projects under this category have a large area of storm drain overflows where the 10-year maximum depth is greater than 12-inches. These projects improve locations with the deepest and longest storm drain overflow situations. They may also be located at the downstream end of many projects, as they would logically be constructed first. Areas of significant historical storm drain overflows fall into this category.
Moderate Priority	This category has conditions similar to high priority, but has a smaller area affected by storm drain overflows. The length and depth of storm drain overflows is less than that of a high priority improvement. Recurring issues are also included in moderate category.
Low Priority	Low priority improvements are generally smaller projects that address minor issues. The areas of storm drain overflows are much smaller and/or briefer in duration than that of moderate and high priority projects.

This section outlines the ultimate improvements for Town-owned system components to achieve a 10-year level of service by alleviating or minimizing predicted storm drain overflows throughout the Town. Each improvement was grouped with nearby improvements that could be undertaken simultaneously and named using a major street or intersection, generally the most downstream, within the group of improvements. In addition, each improvement was given a unique ID that can be used to match with cost tables and maps. The ID contains one letter and a number as shown in Table 5-1. The naming convention is used to identify the improvements in maps and tables. A complete capital improvement plan (CIP) with tables detailing storm drain network improvement projects including existing pipe size, recommended pipe size, and costs for each improvement is available in Chapter 8, Capital Improvement Plan.

Table 5-1: Storm Drain Master Plan Improvements by Type

Project Type	Project ID
Storm Drain Capacity	C
Storm Drain Future Capacity	F
Storm Drain Condition	S[1]
Storm Drain Street Pavement	P
Recurring Issue	N
Creek Culvert	CC

1. Condition project ID matches the site ID in the V&A report, numbering is not chronological

5.4. Moraga System Overview

The modeled drainage area is approximately 4.16 square miles. The modeled collection system within Moraga town limits consists of 981 pipe segments, 1,097 nodes, and 79 outlets. The project area has a total of 141,914 linear feet (26.8 miles) of modeled storm drain pipe equal to or greater than 18 inches in diameter.

5.4.1. Identified Deficiencies Existing Land Use

MIKE-Urban (MU) analysis of the systems for the 10-year design storm shows some storm drain overflows (HGL above the rim elevation of the node) occurring at 107 of the 1,097 nodes. MU predicts a depth of less than 0.5 foot at 23 nodes. Depths between 0.5 and 1.0 foot above the street occur at 15 nodes, and a depth greater than one foot occurs at 69 nodes. A map of the 10-year storm drain overflow depths predicted by the one dimensional MU analyses with no improvements is presented in Figure 5-1.

5.4.2. Identified Deficiencies Future Land Use

Future land use data was used to update hydrologic flows for the future development. The future land use reflects anticipated development expected to occur over the next 20 to 30 years, including projects approved but not yet constructed, as well as development of currently vacant land zoned for residential and commercial uses. The future hydrologic flows were run in MU on the "improved" system, meaning that it is assumed that the Town will improve the high and moderate priority projects within the next 20 years. MU analysis of the future systems for the 10-year design storm shows no additional storm drain overflows caused by development, which is to say that the future system would have capacity sufficient to accommodate both existing and future development if both high and moderate priority improvements are made.

However, new development will contribute runoff to the existing and future storm drain system, and constitute an additional increment of demand to that system. Typically, changes in land use from development will decreases the infiltration rates and increases storm drain flows. An example of this is development of a vacant lot (infiltration rate = 0.175) to multi-residential (infiltration rate = 0.065). Further, developments that intend to tie into an existing system that is currently undersized may exacerbate existing deficiencies. New development should be required to make improvements to the existing system to correct known deficiencies prior to adding additional flows.

In some cases, development is occurring where there is currently no Town maintained facility (e.g. where a hillside drains to a roadside ditch). It is impossible at the level of detail of this study to analyze the impact of developments in areas where there are no existing Town facilities, since the required improvement will be designed based on the project needs and physical characteristics of the site it is assumed that the developer will cover the cost to construct any required new system component, and the cost to analyze any impacts that may occur where the new development ties into an existing system and contributes flows to the system.

The Town of Moraga does not have an aggressive development plan, and most development will maintain the rural feel of the Town. A number of developments are likely to occur on infill sites, and may involve the redevelopment of an existing property that is paved or otherwise developed. In addition, newer development requirements under the Municipal Regional Permit (see Section 7.9) limit the amount of runoff that can be contributed from developments. The Town also requires that new developments greater than 1.0 acre do not increase the 10-year flows from the site above the existing condition.

Nonetheless, although this modeling effort does not show any impacts to the improved system from future development, it does not imply that future development will have no impact. This modeling effort is a planning level analysis, and it is expected that more detailed analysis will be conducted on future developments, at the time of application review, to determine project-specific impacts and required improvements. Such analysis can be input as updates to the models to more accurately assess the impacts from future developments.

A map of the future land use 10-year storm drain overflow depths predicted by the one dimensional MU analyses high and moderate improvements made is presented in Figure 5-2.

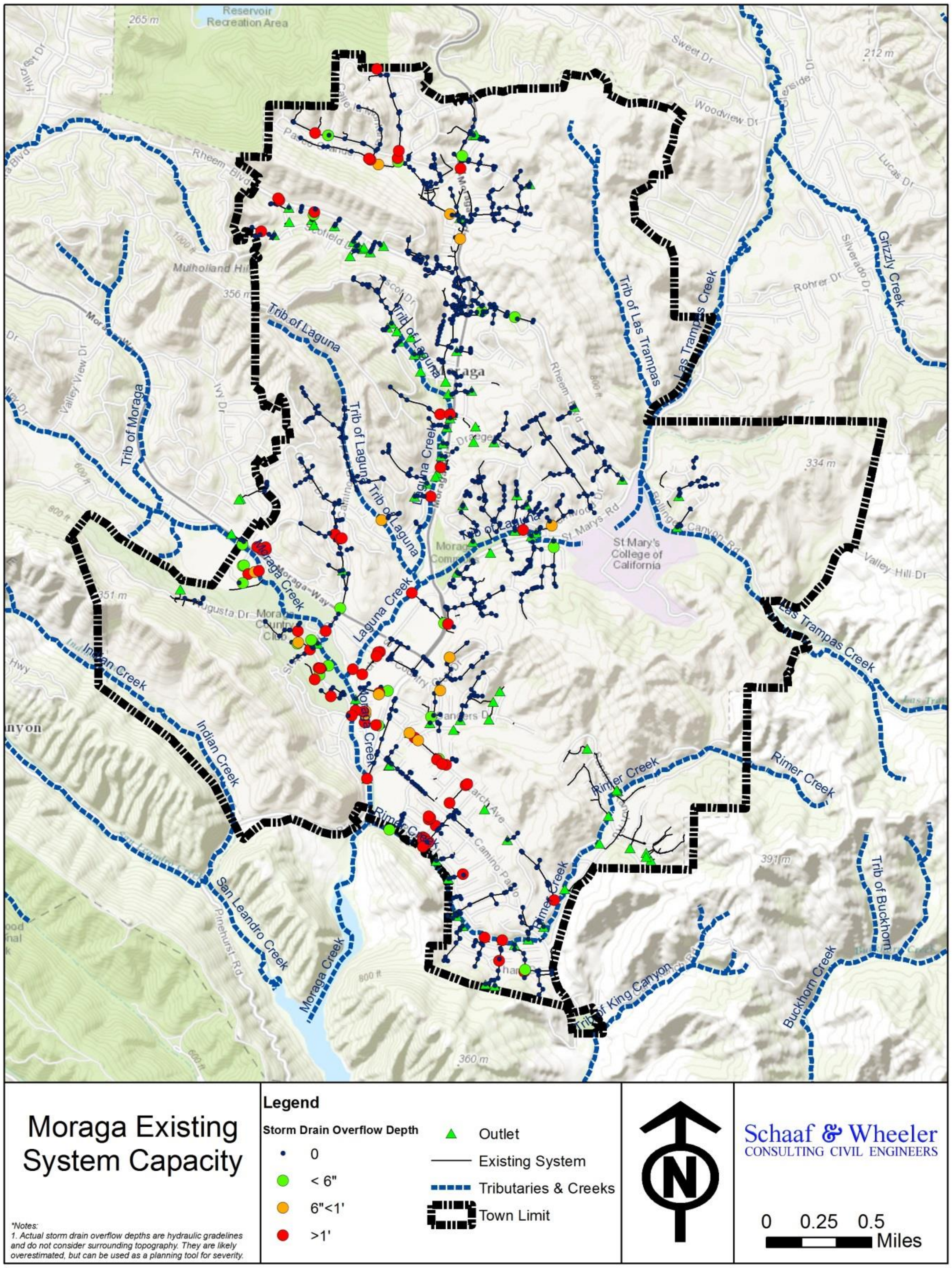

Figure 5-1: Moraga 10-Year Existing System Capacity

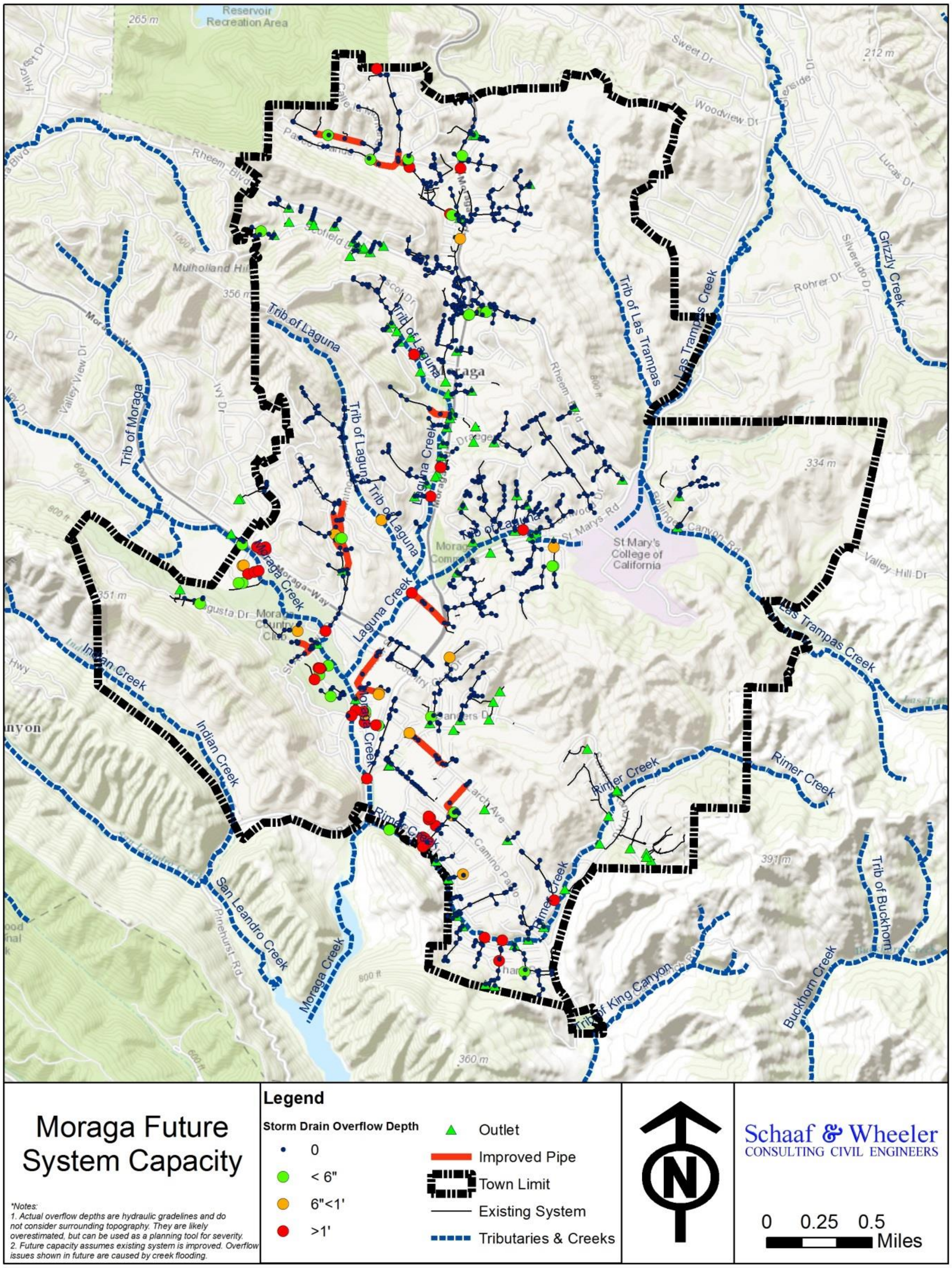

Figure 5-2: Moraga 10-Year Future System Capacity on Improved System

5.5. Prioritized Improvements Capacity

High priority improvements are projects that greatly reduce the risk of storm drain overflows during a 10-year storm event. There are two high priority capacity improvement projects: the Paseo Grande project and the School Street project. The Paseo Grande project, located on the corner of Paseo Grande and Paseo Del Rio, involves replacing several undersized pipes traveling under both the street and Campolindo High School. The School Street project re-routes water flowing along School Street to a nearby outfall. This project also includes upsizing pipes under School Street and Hazelwood Place in order to meet capacity. This project was also identified by the Town as a recurring issue.

Moderate priority improvements are recommended to provide a 10-year level of service at 8 locations. These projects range from upsizing small sections of pipe to large projects requiring significant pipe improvements. The Town may want to re-prioritize these projects based on funding, other utility improvements, and land use changes. Notable projects are Camino Ricardo 1 and Thune, which include installing new pipes on public right-of-way to mitigate storm drain overflows from pipes located on private property.

Low priority improvements are recommended at 9 locations. These projects would eliminate recurring issues and may only get built if there are significant changes to land use, roadway or redevelopment projects in the area.

Figure 5-3 shows prioritized system capacity improvements in Moraga. Appendix D contains project sheets detailing each project.

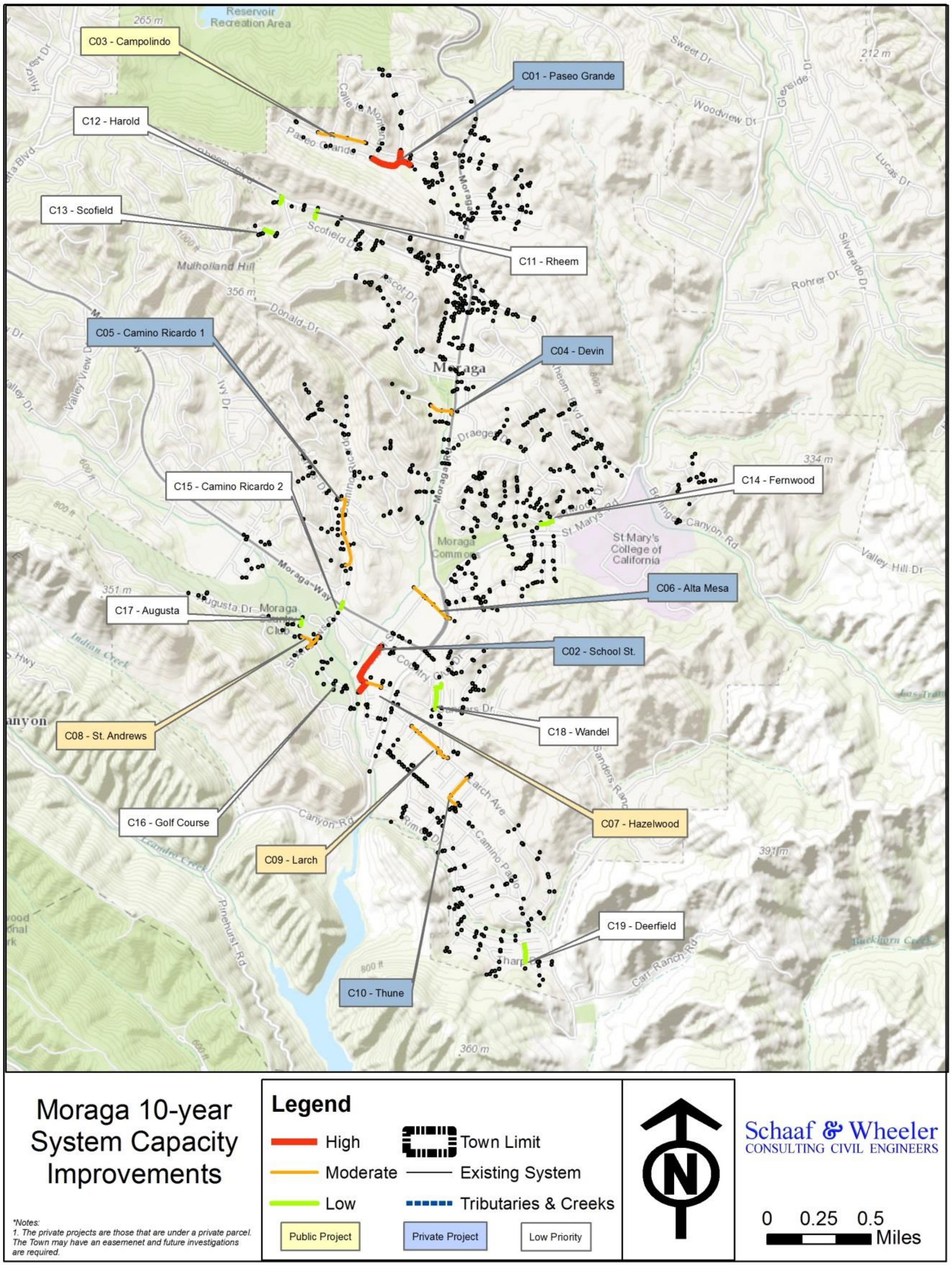

Figure 5-3: Moraga 10-year Capacity Improvement Projects

5.5.1. Future Condition Capacity Improvements

At this time, there are no future condition improvements recommended, however, more detailed modeling is suggested on individual developments to accurately access impacts that each development might have on the existing system. This is due to the fact that much of the anticipated future development is occurring in locations where there is no existing Town storm drain infrastructure to analyze under the current modeling efforts. It is expected that future development will decrease infiltration rates and increase storm drain flows. The additional flows will impact the existing system, especially in areas where there are already improvements identified.

5.6. Prioritized Condition Based Improvements

The overall condition of the storm drain system in Moraga is very good. The majority of pipes and structures inspected by V&A were in excellent or good condition. Less than 15% of the features inspected were prioritized as a 4 or 5 (poor or immediate attention). Figure 5-4 below depicts the results of the condition assessment.

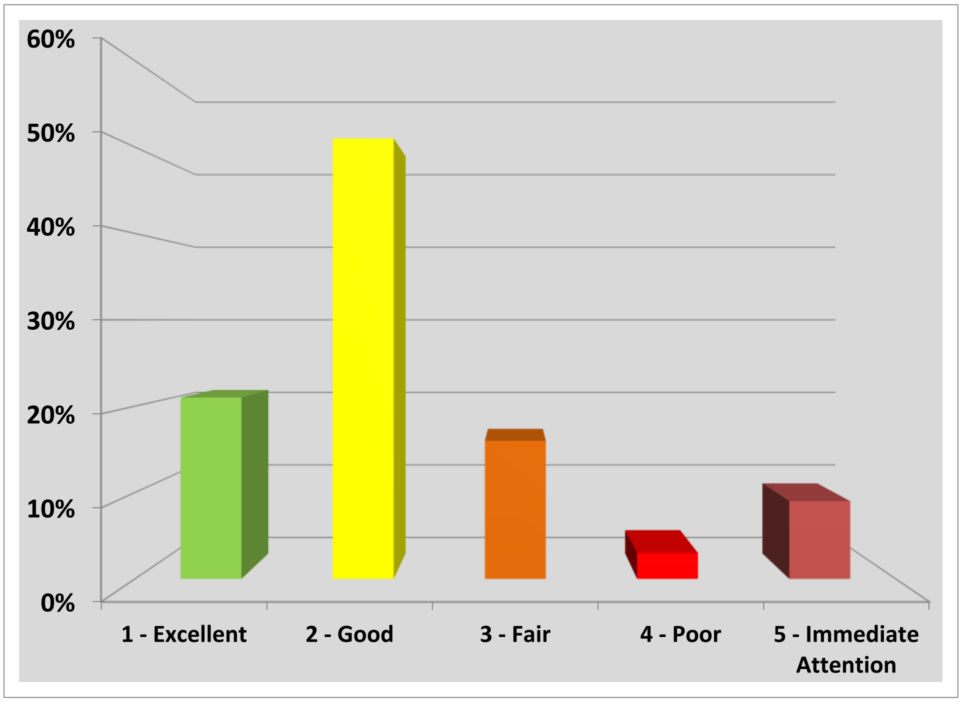

Figure 5-4: Condition Rating of Assessed Features

High priority condition CIPs are projects with severely deteriorated pipes or pipes that are in poor condition under a major roadway where storm drain overflows could have significant impacts. There are seven high priority condition projects in Moraga, with a priority of 5 (defect warrants attention as soon as practical) assigned as part of the Condition Assessment by V&A (see Attachment A). These are at 423 Canyon Road, Rheem Shopping Center, Joseph Drive, Bollinger Canyon Road and Moraga Road near Paseo Linares projects. The Rheem Center culvert is very large (8-feet diameter) and conveys Laguna Creek. This is the highest of all priorities due to the large capacity of the pipe. This pipe also runs under privately owned parcel, and it is unclear if a public drainage easement exists.

Moderate priority condition CIPs are pipes that have been assigned a priority rating of 4 (poor) or a VANDA (reinforced concrete and metal condition index) rating of 3 (moderate damage). There are 2 moderate priority condition improvement projects.

Low priority improvements are recommended to replace or rehabilitate pipes in fair structural condition but with a VANDA rating of 3 or less (moderate to severe corrosion). There are 12 low priority improvements. Figure 5-5 shows all the improvement projects by priority. Pipes under a private parcel are labeled in blue. This does not necessarily mean that the Town does not have an easement over the pipeline, but further investigation should be conducted to determine ownership and maintenance responsibilities.

It is estimated that approximately 3% of the entire system was assessed by V&A. It is recommended that a program be developed to continue condition assessment to assess the condition of the remaining publicly owned pipes in the Moraga storm drain network. This annual program is further discussed in Chapter 8.

Sediment and debris were noted in several pipes. While, the sediment and debris does not compromise the condition of the pipe structure, it can reduce the capacity of the pipes and junctions. Reduced pipe capacity can result in storm drain overflows even if pipes are appropriately sized. It is recommended that the Town continues to maintain catch basins annually and develops a program to clean the pipes each year.

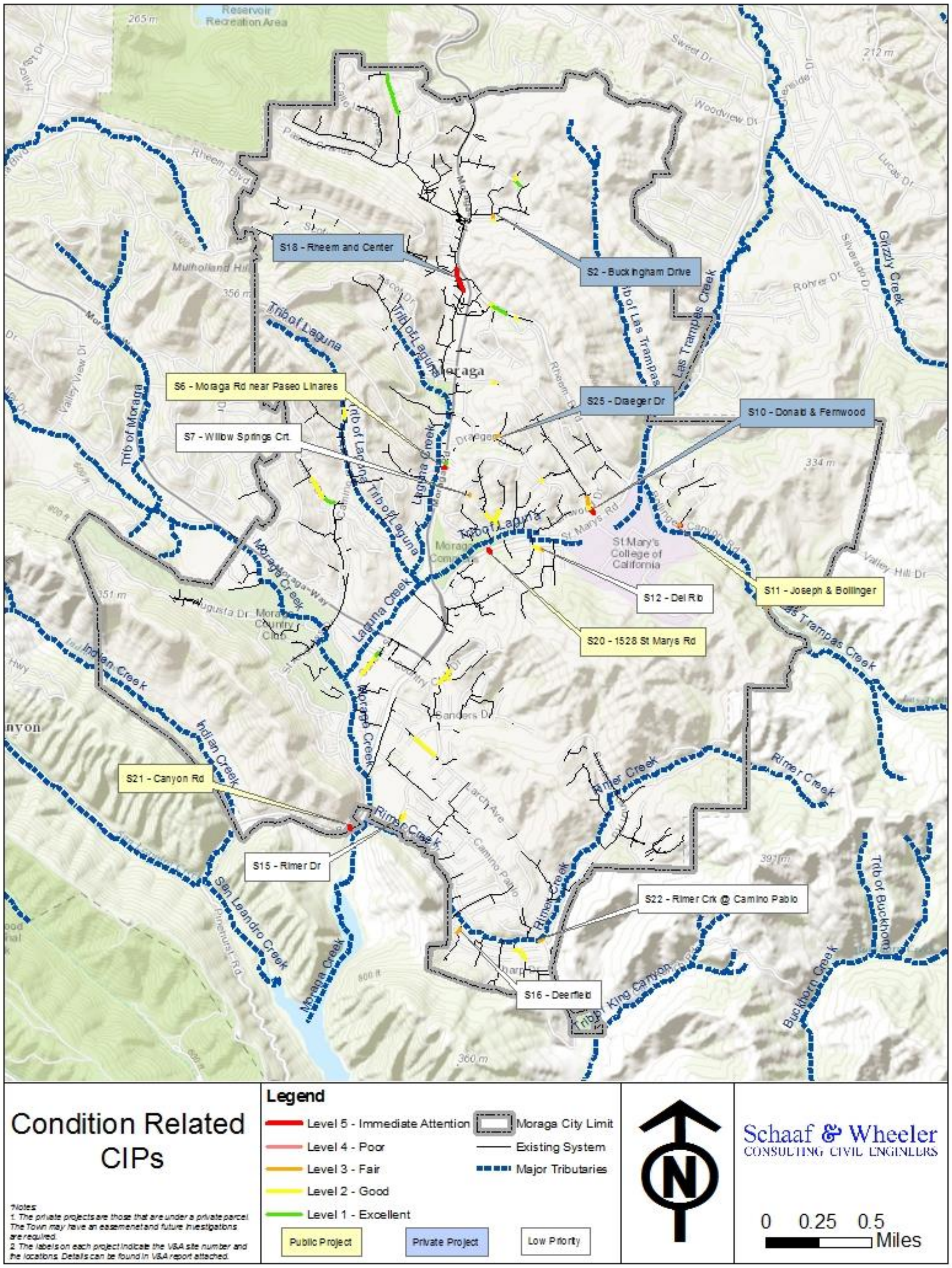

Figure 5-5: Moraga Condition Improvements

5.7. Prioritized Street Pavement Storm Drain Improvements

In 2014, approximately 13,000 linear feet of pipe was televised under streets identified for pavement repairs in 2015. During the inspections, a few pipes were in need of heavy cleaning. Approximately 500 linear feet of pipe was cleaned over one day. In 2008, V&A was hired by the Town to televise 20,000 linear feet of pipe with diameter of 36 inches or greater.

Improvements from the 2014 CCTV data were ranked on a similar scale to condition improvements from 1-5. A complete inventory of improvements was sent to NCE, the Town's consultant for the pavement repair projects. Improvements ranked 4 or 5 were recommended for inclusion with the design of the 2015 pavement reconstruction project. Appendix C contains the report that details all the improvements. Figure 5-6 below shows the location of the improvements. Table 5-2 categorizes the improvements by type. Only projects within the right-of-way were considered for inclusion with the street pavement program.

Table 5-2: Street Pavement Improvements by Type

Project Type	Number of Projects
Cleaning	21
Spot Repair	20
Private Improvement	4
Spot Repair & Cleaning	3
CIPP	2
No Improvement	41
Cleaning Completed	6

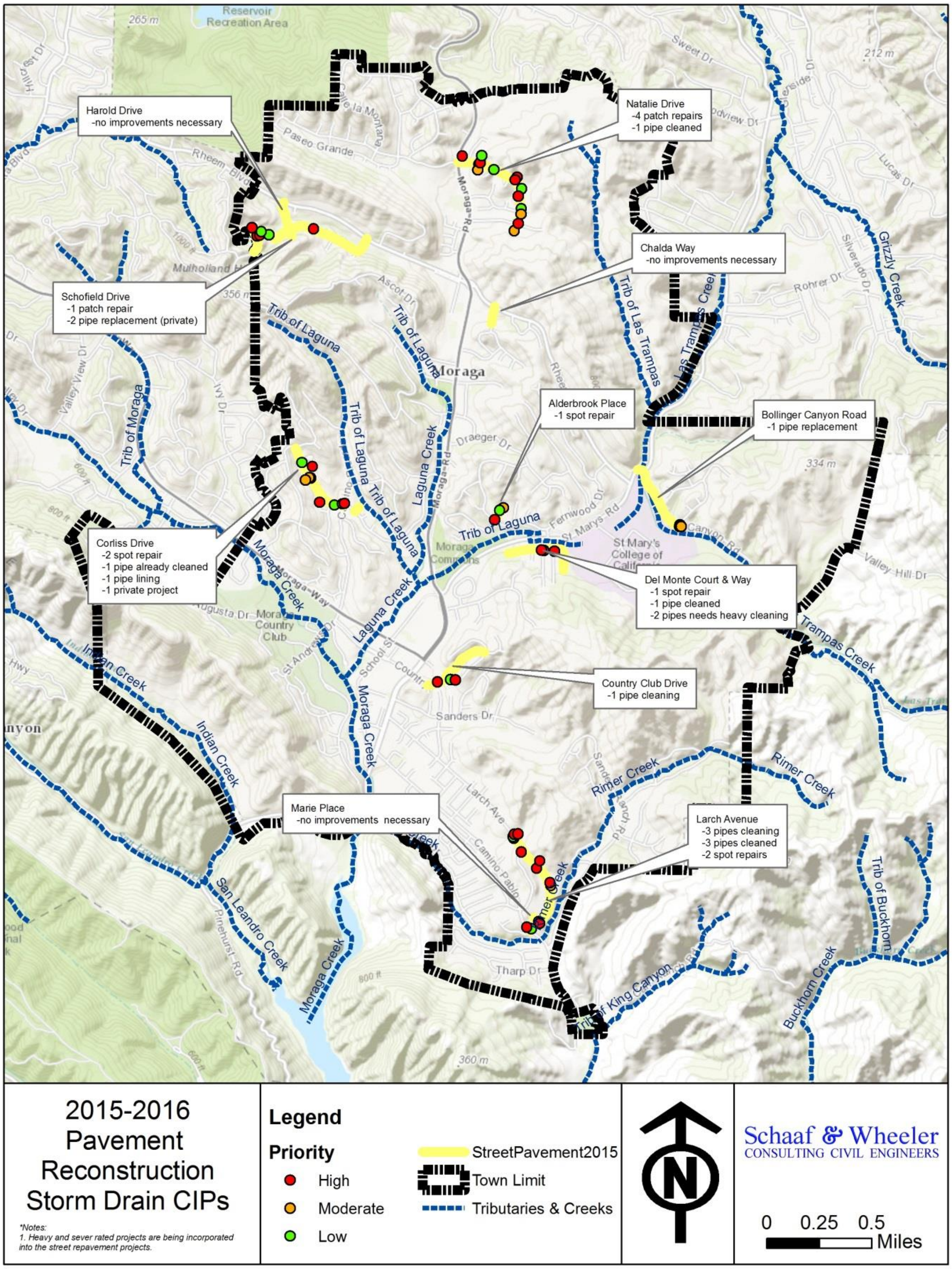

Figure 5-6: Moraga Pavement Reconstruction Project Storm Drain Improvements

5.8. Recurring Issues

Recurring issues are drainage related issues that may or may not have been identified in the modeling or condition assessment efforts. The Town identified eight areas that reported issues in the past. Two of the areas have improvement projects developed from the storm drain and creek culvert systems analyses. Improvements for recurring problems were placed into the moderate priority category as they do not affect properties, but have been noted for causing water hazards on the roadway in the past. Table 5-3 lists the eight locations of recurring issues and the proposed improvement. Figure 5-7 shows the locations of these improvements.

Table 5-3: Recurring Issue Improvements

Improvement ID	Problem Location	Issue	Improvement Type
N01	End of Joseph Drive	Bubbler used to cross utilities that has constant standing water drain with standing water and mosquito issue	Immediate solution to install drain rock. Ultimate solution to connect to downstream system. Needs geotechnical investigation.
N02	Moraga Rd. and Dolores St.	Water gets trapped on the East side of the median on Moraga Rd.	Add inlet and cross culvert to drainage system on West side of road.
See Creek Culverts	St. Mary's Rd. at Town limit	Creek culvert undersized	Part of creek culvert improvements
N03	Ascot Dr. and Moraga Rd	Water ponds at intersection, no inlet	Add inlet and 250' of 24" storm drain pipe to nearest system
N04	Larch Ave. at Creek Crossing	High water from creek crossing, channel highly overgrown with vegetation	Culvert analysis found culvert has capacity, might consider more vegetation maintenance from private residents along creek
N05	End of Camino Ricardo	Riser structure fills with sediment and can become clogged causing maintenance issues and high water	Riser is functioning as is expected, pipe along Camino Ricardo is clean of sediment. Annual maintenance program should be established with spot cleaning prior to large storm events or prior to rainy season
N06	Corliss Dr. near Crossbrook Dr.	Small culverts on downstream side of creek crossing are clogged with sediment	Routine maintenance of culvert to keep clear of debris, consider trash rack on upstream manhole
See storm drain improvements	School Street South of Country Club Dr.	Storm drain is backed up by high waters in the creek and overflows the streets	Part of storm drain improvements

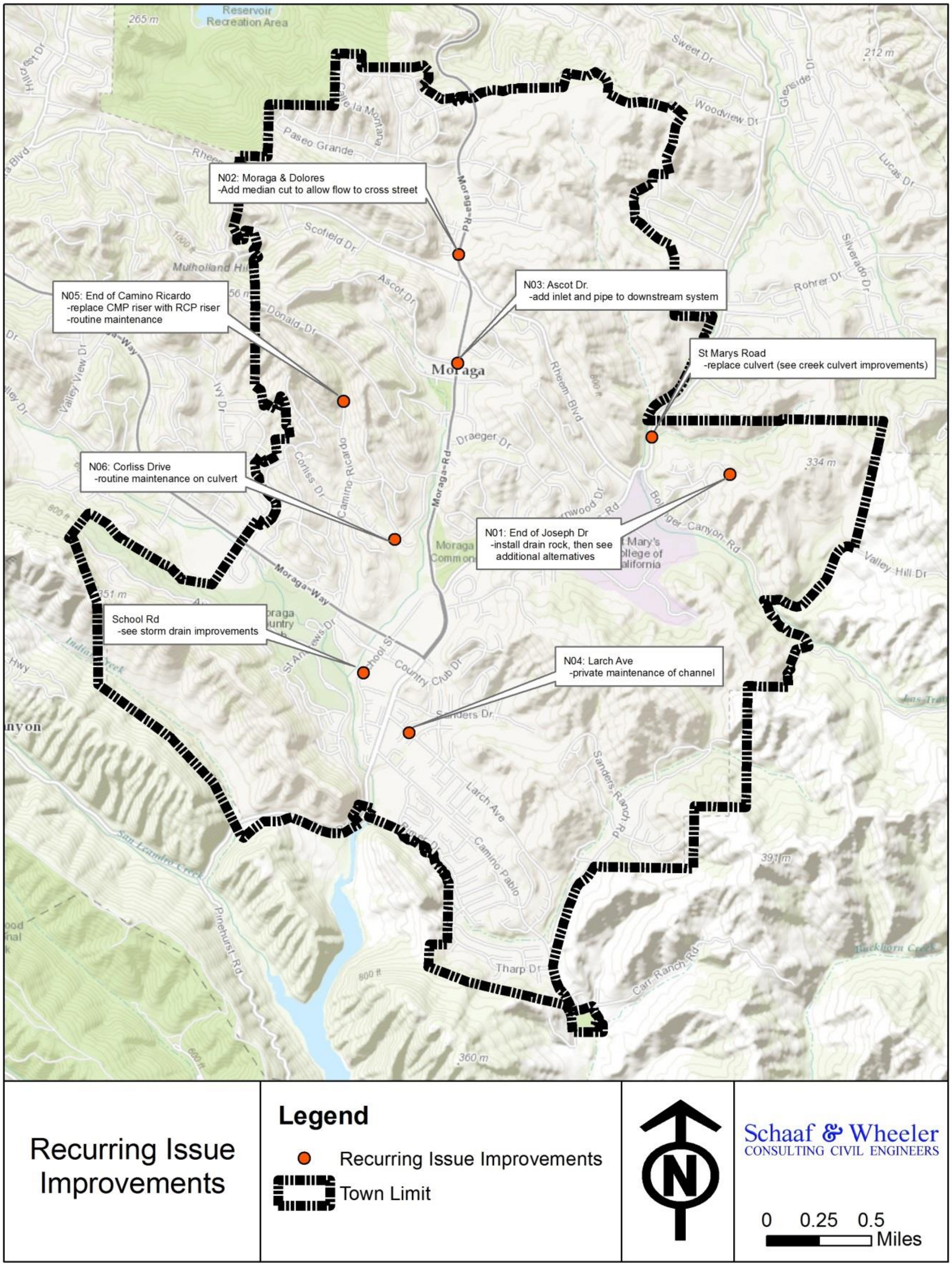

Figure 5-7: Identified Recurring Storm Drain Issues

5.9. Storm Drain Easements

RJA was hired to verify the mapped easements and/or dedications under private parcels. RJA researched the filed subdivision maps to determine if an easement and/or dedication was recorded. This information was then added to GIS by S&W. Detailed research of the past Council meeting notes would help determine if the easement and/or dedication was accepted by the Town. This research is not part of this SDMP. Figure 5-8 shows the pipes with and without recorded storm drain easements.

For the purposes of this report, any pipe under a private parcel is considered private. In cases where private improvements were identified, attempts were made to improve the system within the right-of-way (ROW) to alleviate the need to access private property.

Although this master planning effort was focused on Town-owned facilities, private pipes were included in the models because it is impossible to build a model without the private pipes as they are integrated with the public system. In some cases improvements were identified under private parcels where Town owned facilities connect to pipes under private parcels. The improvements are identified as private; however, the Town may take further steps to identify if an easement was accepted. The Town may consider acquiring easements or accepting dedications where they exist to gain access for maintenance and repair of private pipes. Further evaluation of ownership and responsibility is recommended as project design proceeds.

Unfortunately, there is no industry standard on how to handle pipes under private property. It is not uncommon for jurisdictions to have storm drain pipes crossing under private parcels and each jurisdiction handles these pipes based on policy and legal considerations.

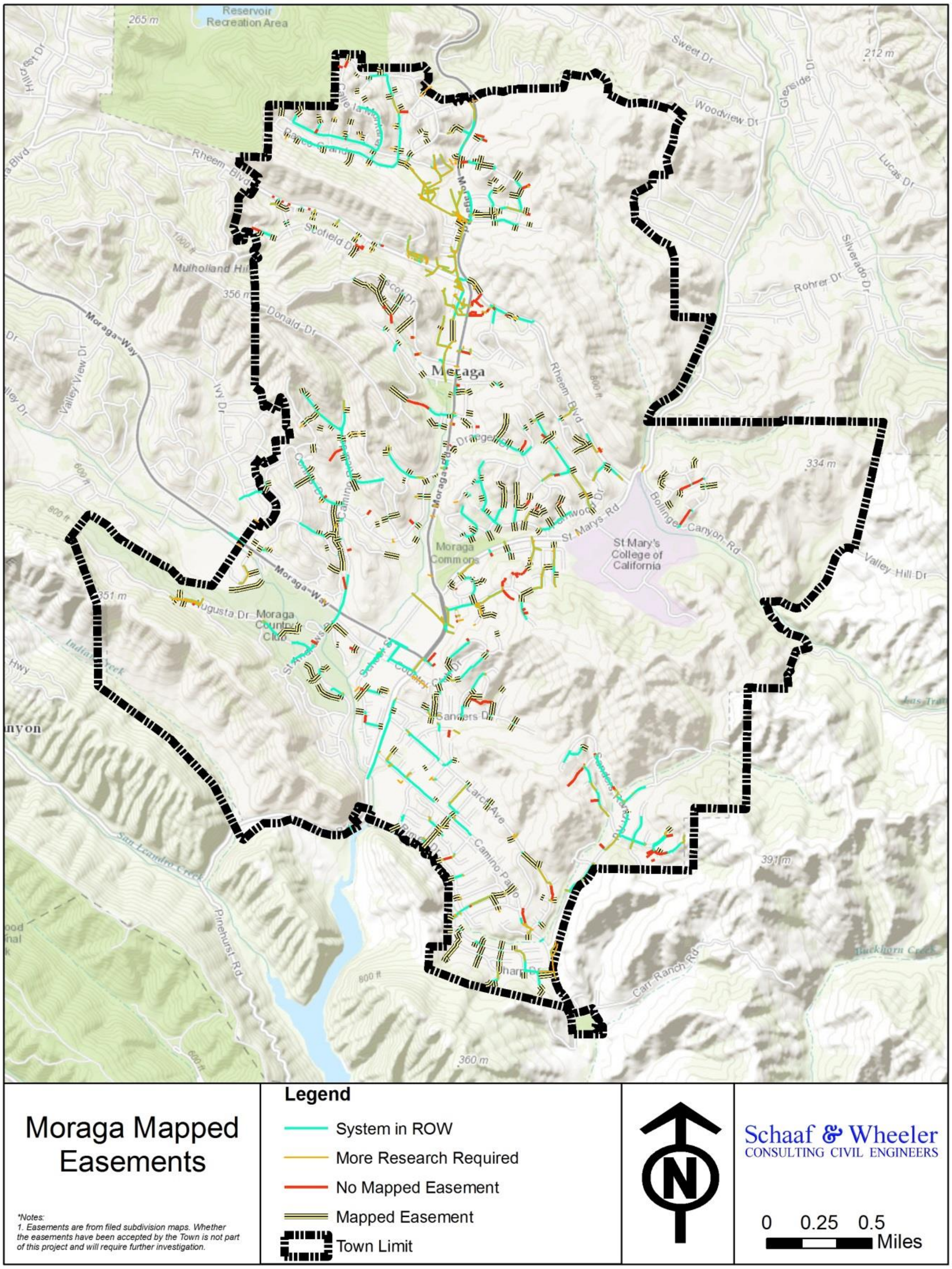

Figure 5-8: Recorded Storm Drain Easements

5.10. Facility Monitoring

Apart from the Capacity, Condition, Street Pavement, and Recurring related projects, S&W also recommends that the Town implement a Facility Monitoring program to re-visit pipes with a condition rating of 3 or 4, as well as to investigate pipes not assessed as part of this Storm Drain Master Plan. It was noted that approximately 20% of the total pipes visited by V&A were in Fair or Poor condition. Assessing the remaining pipes in the Town's storm drain network is recommended.

5.11. Facility Maintenance

Many of the Town's pipes are steeply sloped from the hillsides and can carry large amounts of sediment and debris that settles in the flat areas. The Town currently cleans the majority of the catch basins each year, but not the pipes. Cleaning the pipes is beyond the capabilities of the Town staff as they do not own a vactor truck. It is recommended that the Town start a routine maintenance program of the pipes, starting with those in flat areas where large amounts of sediment and debris have been noted. Figure 5-9 highlights the pipes that have flat slopes (blue) where higher loads of sediment and debris are anticipated. These pipes have slopes less than 3%.

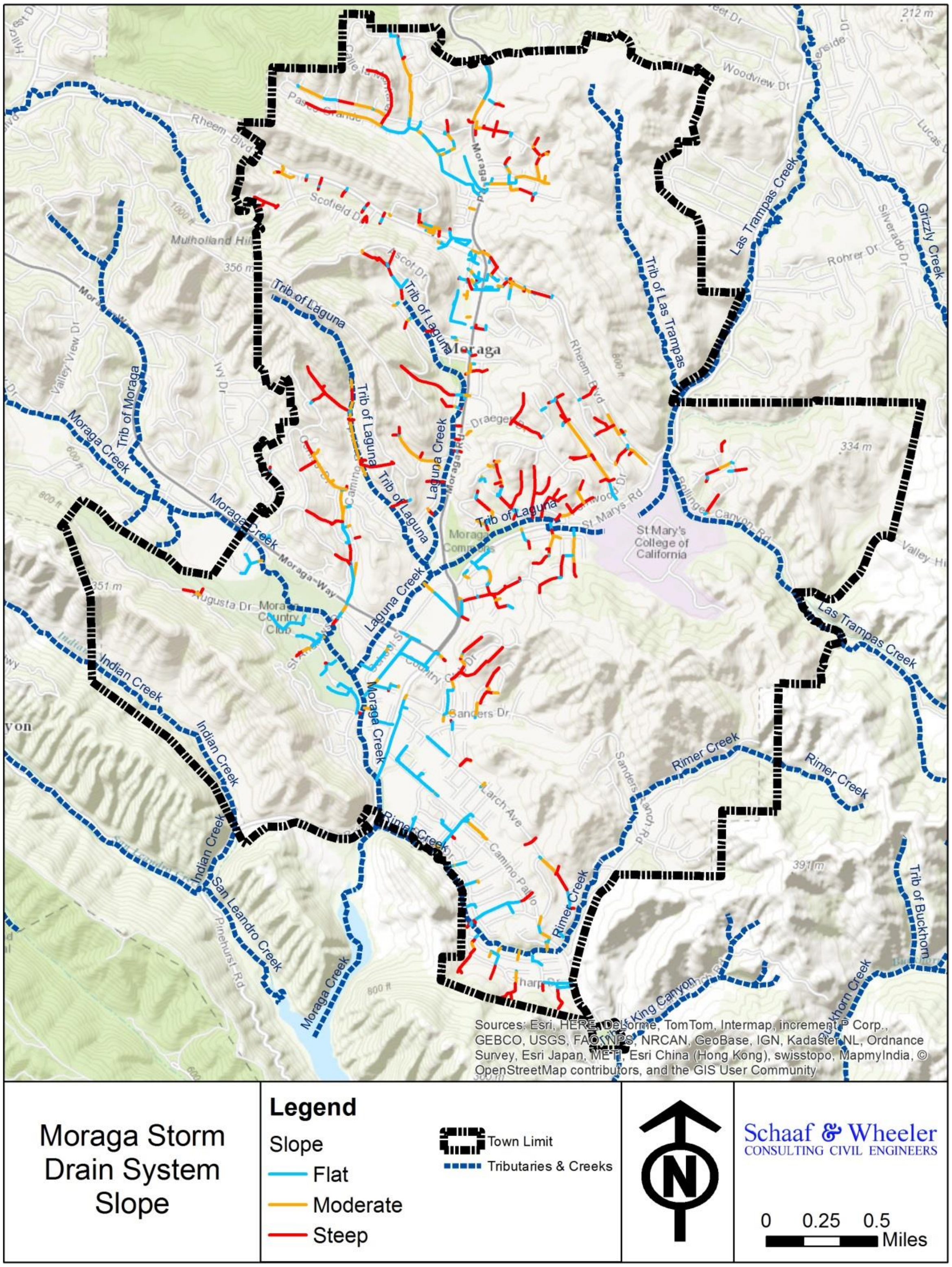

Figure 5-9: Moraga Storm Drain System Slope

Chapter 6. Evaluation of Creek Culvert System

6.1. Overview

This chapter describes major creek culvert facilities throughout the town that convey creek and tributaries under roadways and trails. Culverts recommended for improvements are identified and prioritized herein. This chapter presents the 100-year predicted flooding depths based on published FEMA flows.

6.2. Evaluation of the Creeks

Each creek system was analyzed for existing FEMA published 100-year flows. Culverts that are undersized causing creek flooding over the roadway are recognized herein along with the recommended improvements to improve system performance.

6.2.1. Design Criteria

The capacity of the creek culvert system was analyzed under the 100-year storm event. The 100-year storm has a 1% chance of occurring every year.

6.3. Prioritizing Deficiencies and Needed Improvements

The majority of creek culverts in Moraga are Town-owned, however there are a few culverts that are privately owned and maintained. Recommended master plan improvements are described in the following discussion. Locations for recommended system improvements are based on the results of HEC-RAS models and information provided by Town staff. The recommended improvements are prioritized based on the results of the above process, combined with consideration of the anticipated severity of creek flooding at each location and the benefit/cost relationship of proposed improvements. The following color code is used to highlight project prioritization:

Improvement Priority	Priority Description
High Priority	Projects under this category have a large area of creek flooding where the 100-year maximum creek depth is greater than 12-inches over the roadway. These projects improve locations with the deepest and longest creek flooding situations. They may also be located at the downstream end of many projects, as they would logically be constructed first. Areas of significant historical creek flooding fall into this category.
Moderate Priority	This category has conditions similar to high priority, but has a smaller area affected by creek flooding. The length and depth of creek flooding is less than that of a high priority improvement. This category also includes creek flooding issues that are caused when upstream or downstream culverts are improved.
Low Priority	Low priority improvements are generally smaller projects that address minor creek flooding or maintenance issues. The area of creek flooding is much smaller and/or briefer in duration than that of moderate and high priority projects.

6.4. Prioritized Creek Culvert Improvements

Based on the HEC-RAS models, numerous culverts were found to be undersized; though they were not identified as undersized in the 2008 Study. This is due to two reasons:

1. the nature of modeling methodology that looks at both upstream and downstream control, and
2. updated field data included into the models.

Out of the 35 culverts analyzed, 17 are undersized to convey the 100-year FEMA flows. Out of the 17 improvements, 5 are prioritized as high priority, 6 as moderate priority, and 6 as low priority. Table 6-1 summarizes the creek culvert improvements and Figure 6-1 shows the location and priority of these improvements. Appendix E contains project sheets detailing each project.

Table 6-1: Creek Culvert Improvements

Project ID	Creek	Culvert ID	Location	Priority	Existing Size (ft)	Improved Size (ft)
CC01	Moraga Creek	MC3	St Andrews Drive	High	22 x 8	22 x 10
CC02	South Moraga Creek	SMC2	Camino Pablo	High	6.5	8
CC03	Laguna Creek	LC2	Woodford Drive	High	3.5	7
CC04	Laguna Creek	LC5	Hacienda de las Flored Property	High	8	8 x 10
CC05	Moraga Creek	MC1	Ivy Drive	Moderate	12.6 x 8	1 x 9
CC06	St. Mary's Rd Trib	STM2	St Mary's Road	Moderate	4	9 x 5
CC07	Ivy Drive Trib	ID2	Moraga Road	Moderate	5.5	8 x 5.5
CC08	Corliss Drive Trib	CD1	Corliss Drive	Moderate	5.67	8 x 5
CC09[2]	Moraga Creek	MC2	Miramonte Drive	Moderate	15 x 8.5	20 x 9
CC10[2]	Ivy Drive Trib	ID1	Ivy Drive	Moderate	5.8 x 3.8	6 x 4.5
CC11	Rheem Trib	RT3	Rheem Boulevard	Moderate	4.5	5
CC12	Rheem Trib	RT1	Scofield	Moderate	5	Clean
CC13	St. Mary's Rd Trib	STM1	Moraga Road	Low	5	7
CC14	Laguna Creek	LC1	Campolindo Drive	Low	4	7 x 4
CC15[1]	Las Trampas	LTC3	Bollinger Canyon Rd	Low	13 x 5	12 x 10
CC16	Las Trampas Trib	LTC2	St Marys Road	Low	4.5 x 2.7	5 x 4

Project ID	Creek	Culvert ID	Location	Priority	Existing Size (ft)	Improved Size (ft)
CC17	St Mary's Rd Trib	STM4	Lafayette/Moraga Trail	Low	6	8 x 6
CC18	Rheem Trib	RT2	Harold Drive	Low	3.5	Clean

1. This culvert is very close to the Town limit and was included in the study but has been termed "private."

2. These culverts are on the border with the City of Orinda and any improvements should be coordinated with the City of Orinda.

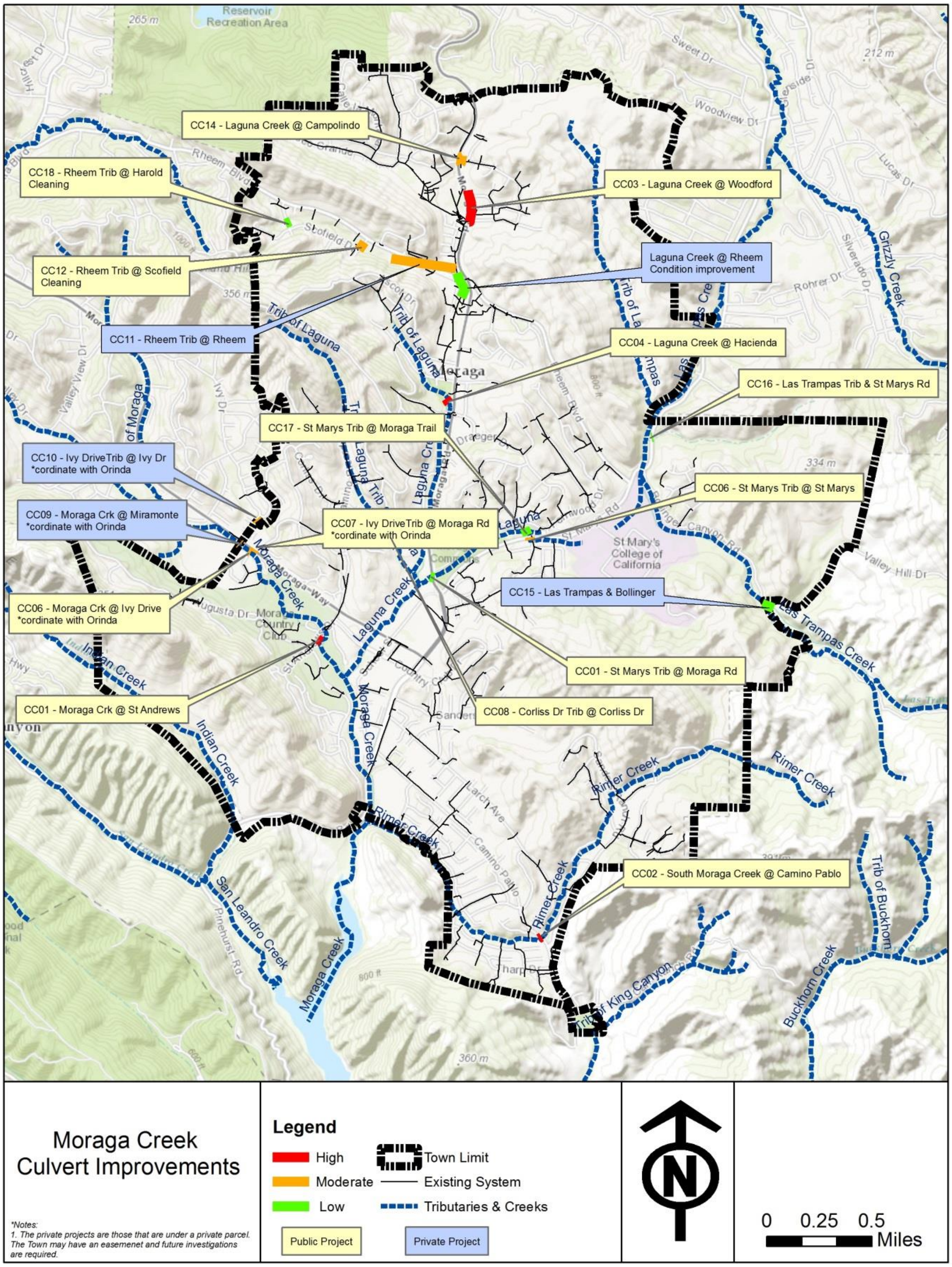

Figure 6-1: Creek Culvert Improvement Locations

6.5. Channel Day-lighting Alternative Projects

An alternative to the replacement of existing undersized pipe systems is day-lighting. This will involve replacing buried pipe networks with vegetated earthen channels, with cross culverts or bridges at roadway crossings, particularly where natural drainage channels and streams have been previously piped. This alternative would discourage unwise development encroachment, improve access and safety, enhance water quality, reduce sediment, and increase aesthetics compared to traditional pipe replacement projects.

Open channel alternatives may not always be a viable alternative for every improvement project due to right-of-way issues, hydraulics, safety, or economic limitations. From the creek culverts assessed, only the culvert near the Hacienda (LC5) has an opportunity to daylight the creek as rest of the creek culverts convey major roadways over the creeks. Laguna Creek was another project that was looked at for potential day-lighting options but due to property ownership and the depth of the culvert it is not a good candidate for day-lighting. Box culverts have been recommended that will act more like bridges with earthen channel bottoms to provide a more natural feel.

Chapter 7. Regulatory Guidelines and Requirements

7.1. Overview

National, regional, and local regulatory guidelines and requirements did not affect how improvements were developed, but will need to be taken into consideration when implementing the master plan improvements recommended in Chapters 5 and 6. Consideration should be taken in the following areas:

- Floodplain management
- Stormwater management
- Surface water protection
- Groundwater protection
- Riparian and wetland protection

The most significant regulatory requirements for stormwater management in Moraga are found in the State of California's Construction General Permit (CGP) and the San Francisco Bay Municipal Regional Stormwater Permit (MRP) under the National Pollutant Discharge Elimination System (NPDES). This chapter provides a general outline of the various guidelines along with legal and regulatory requirements applicable for floodplain management, stormwater management, surface water and groundwater protection and riparian and wetland protection.

Town and private projects within the riparian corridor or near a wetland may also be required to have environmental and water quality permits from the Contra Costa Clean Water Program (CCCWP), San Francisco Bay Area Regional Water Quality Control Board (RWQCB), California Department of Fish and Wildlife (USFWS), and the United States Army Corps of Engineers (USACE).

7.2. FEMA Regulations

Typical insurance policies do not cover the potentially devastating consequences of flooding. Even after a catastrophic event wherein houses and businesses are completely destroyed, property owners remain liable for their mortgage balances without the equity to cover them. The National Flood Insurance Program was created in 1968 for the expressed purpose of providing flood coverage even in the absence of a Presidential declaration of disaster. The intent of flood insurance is to proactively prepare for future flood damages on an equitable basis nation-wide.

7.2.1. National Flood Insurance Program

The National Flood Insurance Program (NFIP) as administered by the Federal Emergency Management Agency (FEMA) allows property owners within participating communities to purchase insurance that protects against losses from flooding. Most banks require mortgage holders to purchase flood insurance if the property is located in a FEMA floodplain. Damages to structures and contents are covered by the flood insurance, which may be purchased through residential and commercial insurance agents. For Moraga to participate in the NFIP, the Town must adopt and enforce a floodplain management ordinance to reduce future flood risks to new construction and substantial improvements to existing structures in Special Flood Hazard Areas. In return, the Federal Government will make flood insurance available in the Town.

7.2.2. Moraga's Participation in the NFIP

The National Flood Insurance Act of 1968 allows FEMA to make flood insurance available only where the community has adopted adequate floodplain management regulations. Moraga joined the NFIP in the mid-1970s, and FEMA issued the first Flood Insurance Rate Map (FIRM) for the Town in 1981.

7.3. Town of Moraga Policy

The Town of Moraga is responsible for ensuring compliance with Federal and State laws that regulate stormwater. The Town operates under the MRP (discussed in Section 7.5), through programs and policies which are outlined in the Stormwater C.3 Guidebook (6th Edition). http://cccleanwater.org/c3-guidebook.html

All master plan improvement projects are subject to Town policy. The following sites provide useful information on Town policies:

Stormwater Management
http://www.moraga.ca.us/dept/publicworks/water

Planning Department
http://www.moraga.ca.us/dept/planning/about

Department of Public Works
http://www.moraga.ca.us/dept/publicworks/about

Hydromodification Management Plan (see Appendix C)
http://cccleanwater.org/c3-guidebook.html

Floodplain Management Code
https://www.municode.com/library/ca/moraga/codes/code_of_ordinances?nodeId=MOCA_TIT8PLZO_CH8.108FLHAARRE

7.4. Construction General Permit (CPG)

The State of California requires that dischargers obtain permit coverage for projects with construction activities that disturb one or more acres in accordance with Construction General Permit Order 2009-0009-DWQ. Construction activity subject to this permit includes clearing, grading, and land disturbances such as stockpiling or excavation. The permit excludes certain regular maintenance activities from obtaining coverage.

The CGP requires the development and implementation of a Storm Water Pollution Prevention Plan (SWPPP). The SWPPP includes a Water Pollution Prevention Drawing that identifies and locates Best Management Practices (BMPs) within the limits of work, and stormwater discharge monitoring and sampling requirements. All master plan improvement projects are subject to the requirements of the CGP.

7.5. Municipal Regional Permit (MRP)

The Town of Moraga is a member of the Contra Costa Clean Water Program (CCCWP or Program) which assists in managing a shared common Municipal Regional Stormwater NPDES Permit to discharge stormwater to the San Francisco Bay which can be found here:
http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/mrp.shtml.

The Town is required to meet all stormwater management requirements set forth by the MRP. The current MRP was adopted October 14, 2009 (Order no. R2-2009-0074), and became effective as of December 1, 2009. In February of 2015, the Regional Board released a draft MRP 2.0 which is meant to replace the 2009 permit by the end of 2015.

The MRP outlines the State's requirements for municipal agencies in the San Francisco Bay Area to address the water quality and flow-related impacts of stormwater runoff. The MRP is a comprehensive permit that requires activities related to construction sites, industrial sites, illegal discharges and illicit connections, new development, and municipal operations. The permit also requires a public education program, implementing targeted pollutant reduction strategies, and a monitoring program to help characterize local water quality conditions and to begin evaluating the overall effectiveness of the permit's implementation.

The requirements of the MRP will need to be considered during construction of all master plan improvements.

7.6. Contra Costa Clean Water Program (CCCWP)

The Contra Costa Clean Water Program (CCCWP) is dedicated to maintaining a healthy environment in Contra Costa's beautiful creeks, rivers, the Delta and the Bay. The CCCWP assists the municipalities to comply with the NPDES Permits by providing guidance and staff training and by implementing some public outreach and water-quality monitoring that can be done more cost-effectively at the countywide level.

Coordination with CCCWP will be required for the construction of master plan improvements located on stream banks. This includes the creek culvert improvements and/or the construction of new outfalls.

7.7. United States Army Corps of Engineers (USACE)

Under Section 404 of the Clean Water Act (CWA), the United States Army Corps of Engineers (USACE) regulates certain activities that "discharge dredged or fill material into waters of the United States". Waters of the U.S. are defined to generally include such resources as tidal waters, most rivers, lakes, and streams, and certain types of wetlands. Channel stabilization and stream maintenance activities that propose to place fill, e.g. culverts, gabions, rock rip rap, logs, etc., in the channel must obtain a permit from USACE.

USACE issues two types of permits under Section 404: general permits and standard (individual) permits. General permits are issued by USACE to streamline the permit process, while individual permits are more rigorously reviewed and are reserved for projects that impact more than 1/3 acre of tidal waters or non-tidal waters greater than 1/2 acre. Specifically, the USACE Nationwide Permit (NWP) program authorizes 43 different categories of activities, each of which is governed by specific conditions for the particular NWP, as well as 27 general conditions that apply to all NWPs.

A permit will need to be obtained from USACE for the construction of improvements that will impact waters of the U.S. This includes the alteration of existing outfalls, the construction of new outfalls, and any construction in a marsh, wetland, or tidal waters.

7.8. Bay Area Conservation and Development Commission (BCDC)

On a regional level, the San Francisco Bay Conservation and Development Commission (BCDC) regulates projects proposing to fill, extract materials, or change the use of water, land, or structures in or around San Francisco Bay. Fill is very broadly defined to include (1) solid fill, such as dirt, concrete, wood, and structures, (2) pile-supported fill, such as fixed boat piers and docks, (3) floating fill, such as floating docks, houseboats, and vessels moored for extended periods of time, and even (4) structures cantilevered over BCDC's jurisdiction. BCDC's permit jurisdiction includes San Francisco Bay which is defined as any area within the greater San Francisco Bay up to mean high tide (except in areas of tidal marsh where the BCDC jurisdiction extends to 5 feet above mean sea level) and a "shoreline band" that extends 100 feet inland from areas subject to tidal action.

A study will need to be completed to determine which projects in Moraga fall under BCDC jurisdiction. Only the alteration of existing outfalls, the installation of new outfalls, and the replacement of creek culverts are expected to require permits.

7.9. Low Impact Development (LID)

As of December 1, 2011, the MRP requires Low Impact Development (LID) treatment requirements for all new development and redevelopment projects. The term LID refers to practices that reduce water quality impacts by preserving and re-creating natural landscape features, minimizing imperviousness, and using stormwater as a resource, rather than a waste product. These measures include rainwater harvesting/reuse, infiltration, and evapotranspiration. If these measures are deemed infeasible, then bioretentiont can be used. It is likely in the future more and more emphasis will be placed on using the following technologies on construction sites recommended by the Water Board:

1. Bioretention & Rain Gardens
2. Rooftop Gardens
3. Sidewalk Storage
4. Vegetated Swales, Buffers & Strips; Tree Preservation
5. Roof Leader Disconnection
6. Rain Barrels and Cisterns
7. Permeable Pavers
8. Soil Amendments
9. Impervious Surface Reduction & Disconnection
10. Pollution Prevention & Good Housekeeping

Because of the emphasis that the MRP puts towards using LID, there are numerous regional groups tracking the most up to date technologies on LID and the corresponding NPDES regulations. The following sites contain useful information for municipal staff, developers, general public, and elected officials to keep abreast with trends and policies in the often changing arena.

Town of Moraga
http://www.moraga.ca.us/dept/publicworks/water

CASQA
http://www.casqa.org/LID/tabid/240/Default.aspx

California State Water Resources Control Board
http://www.waterboards.ca.gov/water_issues/programs/low_impact_development/

CCCWP
http://www.cccleanwater.org/

U.C. Davis
http://extension.ucdavis.edu/unit/center_for_water_and_land_use/low_impact.asp

BASMAA Development Committee
http://basmaa.org/BoardandCommittees/Development.aspx

Urban Design Tool
http://lid-stormwater.net/index.html

Chapter 8. Capital Improvement Plan

8.1. Overview

Chapters 5 and 6 discuss Moraga's storm drain collection system and creek culvert system and recommend prioritized capital improvements to address deficiencies and condition. This chapter provides a Capital Improvement Plan (CIP) that recognizes these priorities. The CIP provides an overall guideline for the Town to use as a tool in preparing annual budgets. However, exigent circumstances (e.g., available funding) and future in-field experiences may necessitate deviations from the Storm Drain CIP. A master plan is intended to be a tool for planning. Capital improvement priorities are not intended to be hard and fast.

The CIP does not include the cost of new facilities related to new development (e.g., pipeline extensions to serve areas that are currently undeveloped). These new facilities may be constructed as part of the new developments, and are not included in the CIP. A Nexus Study is currently underway to determine a development fee based on the increase of storm drain flows anticipated from future development land use changes.

8.2. Open Trench Improvements

Two essential types of projects are traditionally utilized to increase storm drain system capacity:

- install a new relief storm drain parallel to the system lacking capacity, or
- replace the overloaded pipe with larger diameter pipe in the same alignment.

The two alternatives can be made equivalent to one another using the following formula, assuming that pipe material and length are equal:

$$D_R = (D_e^{2.63} + D_p^{2.63})^{0.38}$$

where D_R = diameter of replacement pipe;

D_e = diameter of overloaded pipe; and

D_p = diameter of parallel relief drain.

Assuming the existing pipe is adequate in terms of condition, the installation of a new parallel pipe is typically more cost effective than pipe replacement because the required pipe size is smaller and the existing pipe does not need to be removed. This does not take into account the long term maintenance associated with a parallel system, nor the remaining life of the existing pipe. The selection of a capacity improvement strategy will vary from project to project, and be governed by field constraints such as conflicting utilities, rights-of-way, environmental concerns, permit requirements and traffic control.

8.3. Trenchless Improvements

Traditional cut and cover methods of construction will likely be employed for a large portion of the storm drain improvements. However, the utilization of trenchless methods such as bore and jack, directional drilling, cured-in-place pipe (CIPP), slip-lining, pipe bursting, and others, may increasingly find application in special circumstances where existing development encroaches upon the pipe alignment, or disruption of other services and land uses is too costly. These trenchless methods also have their own constraints and should be chosen based on pipe material, access, and other site specific circumstances.

Rehabilitating corrugated metal pipes (CMPs) accounts for the majority of condition related improvement. Using a CIPP is the preferred method for rehabilitating CMP storm drains or culverts because of the ease of installation and the liner will provide structural stability. Although a CIPP decreases the diameter slightly, it will typically maintain or improve the hydraulic characteristics of the storm drain facility due to the lower roughness coefficients. A detailed analysis should be completed during detailed design to determine if a CIPP liner will maintain adequate capacity for a given site.

8.4. Cost of Improvements

Costs have been estimated using information from other projects, cost estimating guides (2014 Current Construction Costs, Saylor Publications, Inc.), and engineering judgment. All estimates are based on the ENR May 2015 index of 11,173. The cost per linear foot of improvement used for the pipe cost estimates are given in Table 8-1 and Table 8-2 and assume replacement pipe installed using the open trench method (note that these costs do not include the 40% increase for design, administration, and contingency included in all other tables). Costs are likely to vary greatly depending on site specific circumstances; in some cases it may be more practical to use trenchless methods or a parallel pipe for construction.

As per our estimates, connection (manhole or catch basin) replacement cost estimates ranged from $12,134 to $22,000 depending on connecting pipe diameters. Pipe costs include open trenching in the roadway up to ten feet in depth. New outfall costs are estimated to be $40,000 per new outfall. It should be noted that wide variations in actual outfall costs are expected due to location of outfall, whether energy dissipation is required, environmental concerns, etc. Since most of these improvement projects are expected to qualify for negative declarations from permitting agencies, these costs do not include permitting or any environmental documentation.

Table 8-1: Storm Drain Replacement Unit Costs

Diameter (inches)	2015 Dollar per Linear foot of Pipe	2015 Dollar Per Connection
18	$212	$12,134
21	$241	$12,266
24	$262	$12,398
27	$309	$12,530
30	$334	$12,662
33	$364	$12,794
36	$393	$12,926
42	$466	$13,190
48	$534	$13,454
54	$617	$14,559
60	$701	$14,860
66	$796	$16,176
72	$927	$16,510
84	$1,276	$18,849
96	$1,524	$20,721

Note: These costs do not include the minimum 40% increase for design, administration, and for contingency included in all other tables. Unit costs are based on an average 3 feet of ground cover over the pipe. Cost will increase if more than 3 feet of cover is required.

Table 8-2: Cured In Place Pipe (CIPP) Unit Costs

Diameter (inches)	2015 Dollar per Linear foot of Pipe
18	$110
21	$120
27	$145
30	$160
33	$175
36	$190
42	$250
48	$300
54	$390
60	$500
66	$510
78	$530
84	$540
Note: These costs do not include the minimum 40% increase for design, administration, and for contingency included in all other tables.	

8.5. Capital Improvement Program

8.5.1. Storm Drain Improvement CIP

The CIP costs and pipe lengths based on priority level are summarized in Table 8-3. Table 8-4 through Table 8-8 present detailed CIP costs by alternative and project name. All cost estimates prepared by Schaaf & Wheeler include a minimum 40% increase for design, administration, construction management, and contingency. Maps of the improvement priorities with pipe diameters are shown in Chapter 5. Detailed project sheets are included in Appendix D and E.

Table 8-3: Summary of Prioritized 10-Year SDMP CIP - Project Costs

System	High Priority	Moderate Priority	Low Priority	Total
	Cost	Cost	Cost	Cost
Capacity	$2,850,000	$5,110,000	$2,950,000	$10,910,000
Condition	$1,440,000	$40,000	$750,000	$2,230,000
Streets	$280,000	$100,000	$150,000	$530,000
Recurring Issue	---	$150,000	---	$150,000
Creek Culverts	$4,290,000	$5,530,000	$2,290,000	$12,110,000
Total	**$8,860,000**	**$10,930,000**	**$6,140,000**	**$25,930,000**

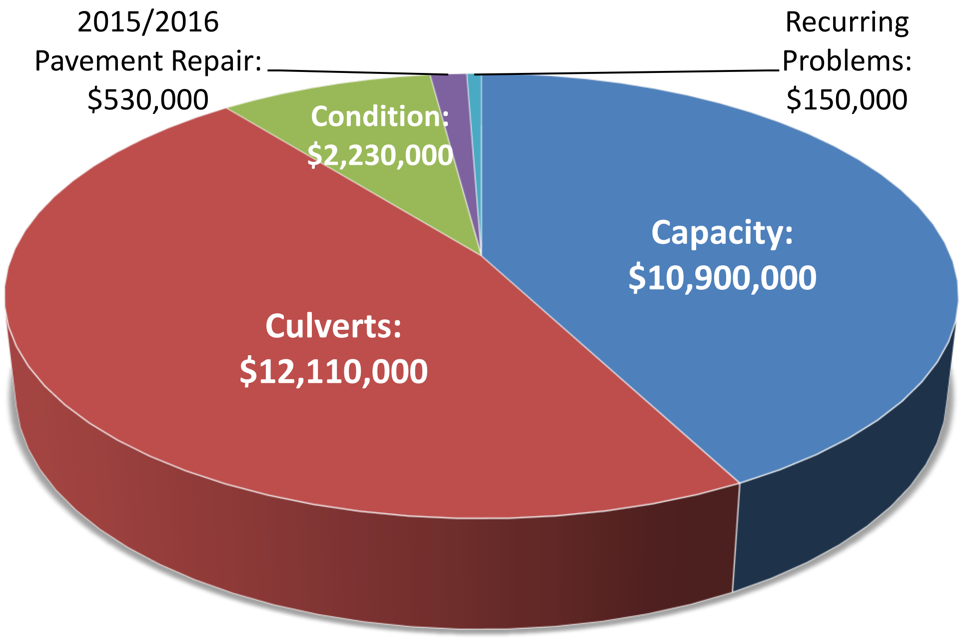

Figure 8-1: Pie chart with percentage for total CIP by Type

Table 8-4: 10-Year Storm Protection Capacity CIP

Project ID - Location	Pipe Length	Connections	Outfalls	Cost	Priority	Cost w/Contingency
C01 - Paseo Grande	1,434	8	-	$1,257,000	High	$1,634,000
C02 - School St.	1,582	6	1	$939,000	High	$1,221,000
C03 - Campolindo	1,229	6	-	$749,000	Moderate	$974,000
C04 - Devin	650	3	1	$351,000	Moderate	$456,000
C05 - Camino Ricardo 1	1,967	7	-	$707,000	Moderate	$920,000
C06 - Alta Mesa	1,216	5	1	$834,000	Moderate	$1,084,000
C07 - Hazelwood	421	3	-	$336,000	Moderate	$437,000
C08 - St. Andrews	758	5	-	$466,000	Moderate	$606,000
C09 - Larch	1,323	7	1	$713,000	Moderate	$927,000

Project ID - Location	Pipe Length	Connections	Outfalls	Cost	Priority	Cost w/Contingency
C10 - Thune	954	3	-	$479,000	Moderate	$622,000
C11 - Rheem	209	4	-	$115,000	Low	$149,000
C12 - Harold	186	3	-	$112,000	Low	$146,000
C13 - Scofield	206	2	-	$89,000	Low	$116,000
C14 - Fernwood	323	2	-	$154,000	Low	$200,000
C15 - Camino Ricardo 2	159	2	-	$141,000	Low	$184,000
C16 - Golf Course	227	2	-	$96,000	Low	$124,000
C17 - Augusta	154	2	-	$138,000	Low	$180,000
C18 - Wandel	756	5	-	$413,000	Low	$537,000
C19 - Deerfield	459	4	-	$305,000	Low	$396,000
					Subtotal	$10,913,000

Table 8-5: 10-Year Storm Protection Condition CIP

Project ID - Location	Pipe Length	Connections	Outfalls	Cost	Priority	Cost w/Contingency
S06 - Moraga Rd.	108	2	-	$53,000	High	$75,000
S11 - Bollinger Canyon & Joseph	139	1	-	$45,000	High	$63,000
S18 - Rheem & Center	599	2	-	$955,000	High	$1,336,000
S20 - 1528 St. Mary's Rd.	109	-	-	$3,000	High	$4,000
S21 - 423 Canyon Rd.	114	-	-	$22,000	High	$31,000
S02 - Buckingham Dr.	125	-	-	$45,000	Low	$63,000
S07 - Willow Springs Ct.	67	-	-	$3,000	Low	$4,000
S10 - Donald & Fernwood	479	-	-	$131,000	Low	$184,000
S12 - Del Rio Way	58	-	-	$3,000	Low	$4,000
S15 - Rimer Dr.	67	-	-	$3,000	Low	$4,000
S16 - Deerfield Dr.	151	2	-	$88,000	Low	$124,000

Project ID - Location	Pipe Length	Connections	Outfalls	Cost	Priority	Cost w/Contingency
S19 - Bollinger Canyon & Valley Hill	161	-	-	$31,000	Low	$43,000
S22 - Camino Pablo & Sanders Ranch	128	-	-	$163,000	Low	$229,000
S25 - Dreager Dr.	110	1	-	$36,000	Low	$50,000
						$2,214,000
Note: Projects are grouped based on the highest priority condition pipe and Project IDs are consistent with the V&A Report.						

Table 8-6: 2015-2016 Street Pavement CIP High and Moderate Priority

Street	Pipe Size (in)	Length Surveyed (ft)	Priority	Cost[1]	Cost w/Contingency
Del Monte Way	15	220	High	$4,000	$6,000
Del Rio	15	39	High	$0	$0
Del Monte	48	4	High	$15,000	$22,000
Corliss	30	612	High	$12,000	$17,000
Corliss	15	0	High	$15,000	$22,000
Natalie	24	290	High	$5,000	$7,000
Scofield	18	110	High	$30,000	$42,000
Scofield	24	83	High	$27,000	$38,000
Scofield	24	97	High	$32,000	$44,000
Natalie	18	34	High	$4,000	$6,000
Natalie	24	134	High	$10,000	$15,000
Campolindo	48	10	High	$17,000	$24,000
Campolindo	48	140	High	$1,000	$1,000
Campolindo	18	26	High	$4,000	$6,000
Camino Pablo	15	15.1	High	$0	$0
Larch	18	62	High	$9,000	$12,000
Larch	15	0	High	$0	$0

Street	Pipe Size (in)	Length Surveyed (ft)	Priority	Cost[1]	Cost w/Contingency
Fernwood Dr	54	52	High	$11,000	$15,000
Bollinger Canyon Rd	30	44	High	$41,000	$0
Alderbrook Place	24	63	Moderate	$10,000	$15,000
Corliss	18	145	Moderate	$4,000	$6,000
Scofield	18	263	Moderate	$4,000	$6,000
Corliss	24	112	Moderate	$15,000	$20,000
Corliss	24	0	Moderate	$0	$0
Country Club	15	21	Moderate	$1,000	$2,000
Sandringham	24	123	Moderate	$5,000	$7,000
Buckingham	24	148	Moderate	$6,000	$9,000
Natalie	30	36	Moderate	$0	$0
Natalie	30	245	Moderate	$6,000	$8,000
Larch	18	34	Moderate	$1,000	$2,000
Larch	24	120	Moderate	$2,000	$3,000
Larch	18	33	Moderate	$1,000	$2,000
Bollinger	24	37	Moderate	$11,000	$15,000
Larch	30	180	Moderate	$6,000	$8,000
Larch	15	12	Moderate	$0	$0
Larch	42	77	Moderate	$0	$0
				Subtotal	**$380,000**

1. Projects listed with a cost of $0 are projects that required cleaning and the cleaning has already been performed.
2. Only high and moderate projects are listed as low priority projects are not part of the 205 street pavement repair projects.

Table 8-7: 10-Year Storm Protection Recurring Issues CIP

Project	Improvement Type	Priority	Cost w/Contingency
N01 - End of Joseph Dr.	Short term project to punch holes in bubbler to allow water to infiltrate and in future connect system to underground system on Joseph Street. Needs geotechnical investigation.	Moderate	$20,000 short term $530,000 long term
N02 - Moraga and Dolores St	Need cut out in median to allow water to flow from one side of street to other	Moderate	$73,000
N03 - Ascot and Moraga	Add inlet and 250' of 24" storm drain pipe to nearest system	Moderate	$134,000
N04 - Larch Ave at Creek Crossing	Culvert analysis found culvert has capacity, might consider more vegetation maintenance from private residents along creek	Moderate	$0
N05 - End of Camino Ricardo	Missouri riser is functioning as is supposed to, pipe along Camino Ricardo is clean of sediment. Annual maintenance program should be established with spot cleaning prior to large storm events	Moderate	$12,000
N06 - Corliss Dr. near Crossbrook	Routine maintenance of culvert to keep clear of debris, consider trash rack on upstream manhole	Moderate	$5,000
		Subtotal[1]	**$244,000**

1. Long term solution on Joseph Street not included in subtotal.

Table 8-8: 10-Year Storm Protection Creek Culvert CIP

Project ID/Culvert ID/Stream	Length (ft)	Shape	Cost	Priority	Cost w/Contingency
CC01- MC3 Moraga Creek	60	Box	$730,000	High	$940,000
CC02- SMC2 South Moraga Creek	120	Pipe	$270,000	High	$350,000
CC03- LC2 Laguna Creek	820	Pipe	$1,530,000	High	$1,990,000
CC04- LC5 Laguna Creek	225	Daylight	$730,000	High	$1,010,000 [1]
CC05- MC1 Moraga Creek	46	Box	$350,000	Moderate	$460,000
CC06- STM2 St Marys Rd Trib	75	Box	$220,000	Moderate	$280,000
CC07- ID2 Ivy Drive Creek	85	Box	$240,000	Moderate	$310,000
CC08- CD1 Corliss Drive Trib	80	Box	$210,000	Moderate	$270,000
CC09- MC2 Moraga Creek	70	Box	$700,000	Moderate	$910,000

CC10- ID1 Ivy Drive Creek	37	Box	$70,000	Moderate	$90,000
CC11- RT3 Rheem Trib	1830	Pipe	$2,450,000	Moderate	$3,180,000
CC12- RT1 Rheem Trib	1830	Pipe	$20,000	Moderate	$30,000
CC13- STM1 St Marys Rd Trib	250	Pipe	$500,000	Low	$660,000
CC14- LC1 Laguna Creek	260	Box	$520,000	Low	$680,000
CC15- LTC3 Las Trampas	70	Box	$380,000	Low	$500,000
CC16- LTC2 Laguna Trib	80	Box	$170,000	Low	$220,000
CC17- STM4 St Marys Rd Trib	50	Box	$160,000	Low	$200,000
CC18- RT2 Rheem Trib	130	Pipe	$20,000	Low	$30,000
				Subtotal	**$12,110,000**

1. Cost Estimate from WRECO "Laguna Creek Hydraulic Study Project," 2014

8.6. System Maintenance, Inspection and Asset Replacement

It is recommended that the Town continue video inspection to get a more detailed picture of the sediment and debris within the pipes to assess any serious defects in the system. CCTV video coverage of the entire Town-owned storm drain network is likely to be very costly. Due to budgetary constraints, this undertaking would likely be completed over the course of several years, possibly focusing on storm drains under pavement projects as was done for the 2015 pavement repair projects. In addition, it is recommended that the Town hire a contractor for 1.5 weeks each year to clean the most heavily impacted pipes. Based on findings in this report, the most heavily impacted pipes are those on flat terrain where debris and sediment settles. Using the results of the 2014 CCTV survey, it is estimated that approximately $200,000 worth of storm drain repairs and replacement would be beneficial. Using the estimate of 15,000 linear feet of pipe televised each year (similar to what was televised in 2014), a budget of $200,000 should be set aside for replacement and repairs. A breakdown of the costs associated with obtaining video, cleaning system, providing engineering recommendations, and replacing and repairing identified problems for the entire network over a period of approximately twenty years is shown below in Table 8-9.

Table 8-9: Annual Video Inspection, Cleaning, and Recommendations Budget

Action	Cost
Video Recording (10,000-15,000 ft.)	$15,000
System Cleaning (1.5 weeks)	$15,000
Technical Assessment/Recommendations	$10,000
Asset Replacement/Repairs	$200,000
Total Annual	**$240,000**

The total number of linear feet recorded per year is expected to be between 10,000 and 15,000. It is possible for the recorded number of linear feet to be higher or lower due to the varying accessibility of individual pipe segments. It is difficult to estimate the linear feet of pipe cleaned within 1.5 weeks as it is dependent on how much cleaning is required. Some pipes may be cleaned in just one hour, while others may require multiple days.

8.7. Title and Easement Research

There are 17 projects rated high and moderate priority that contain pipes under private parcels. The cost of these projects total about $13 million. This amount is over half of the costs of the high and moderate priority projects ($20M). It is recommended that the Town begin investigating property ownership to further evaluate rights and responsibilities. It is estimated that it will cost approximately $40,000 for the Town to hire a consultant to identify the property rights for the 17 high and moderate projects.

APPENDICES

A – V&A Condition Assessment

B – Culvert Assessment Field Sheets and Photos

C – Street Pavement Storm Drain Repairs

D – Capacity Improvement Project Sheets

E – Creek Culvert Improvement Project Sheets