3 IMPLEMENTING LID ON AN ARMY INSTALLATION

3.1 INTRODUCTION

Implementation of LID on an Army installation can be achieved at various levels, from master planning, Installation Design Guides and through planning charrettes and site planning and design for specific projects. This chapter will take the user through LID implementation from the master planning level down to the site specific final design of a LID BMP. For the purposes of meeting the stormwater requirements and EISA Section 438, the site planning sections will guide planners, designers, engineers and stormwater managers through the steps of planning their site to effectively choose LID BMPs that meet the stormwater volume requirements. The master planning and site planning processes require a basic understanding of Army Land Uses and activities and a fundamental knowledge of Army planning and site design Uniform Facilities Criteria (UFC's), Public Works Technical Bulletins (PWTB's), Directives, and Regulations, which are referenced throughout this chapter and listed in Section 1.3.3.

3.2 LID AND INSTALLATION MASTER PLANNING

Army master planning is a continuous analysis of present and future development needs of an installation in a sustainable and energy efficient manner. Through the master planning process, a vision is established for the installation with goals and objectives, which is an opportunity to imbed LID into the future development and management of the installation. Figure 3-1 and Figure 3-2 illustrate the master planning process, from the vision plan for the installation through the Installation Design Guide (IDG), short-term and long-term development planning and project site requirements; from installation scale planning to site planning. While strategizing the layout of land uses and connectivity of resources with functional relationships, water resources and stormwater infrastructure should also be considered. The identification and understanding of the existing natural features, installation land uses, and infrastructure, and the potential hydrologic response of planned development and opportunities to restore hydrologic functions are critical in creating a sustainable installation. This concept can be carried through in the IDG and Area Development Plans (ADP).

An IDG provides design standards and guidelines for the visual aesthetics of an installation, to include both the built and natural environment, to create a comprehensive and sustainable installation character. The IDG includes standards and general guidelines for the design issues of site planning; architectural character, colors and materials; vehicular and pedestrian circulation; and landscape elements. LID should be incorporated into the standards and guidelines for site planning for all land uses, especially for buildings, roads, parking lots and landscape elements. These LID standards and guidelines will carry through to short-term and long-term project requirements and ADPs.

The ADP process uses urban design principles to integrate incompatible land uses and functional requirements within the existing manmade and natural environment. Army land uses can have certain requirements depending on their purpose and security, such as training areas, communications facilities, and other military operations. Integrating the land uses within a functional area for an ADP can present challenges not only with the requirements but also the site

constraints. As many of the land uses can require impervious area, the hydrologic functions of the area need to be considered in the ADP. This is a great opportunity to identify constraints and opportunities for preserving the hydrologic function of the watershed and area by using both non-structural and structural LID BMPs. Identifying these opportunities and including LID in the requirements for project specific plans will help minimize the hydrologic impacts and ensure compliance with EISA Section 438. The remainder of the chapter will take the user through the details of site planning with LID.

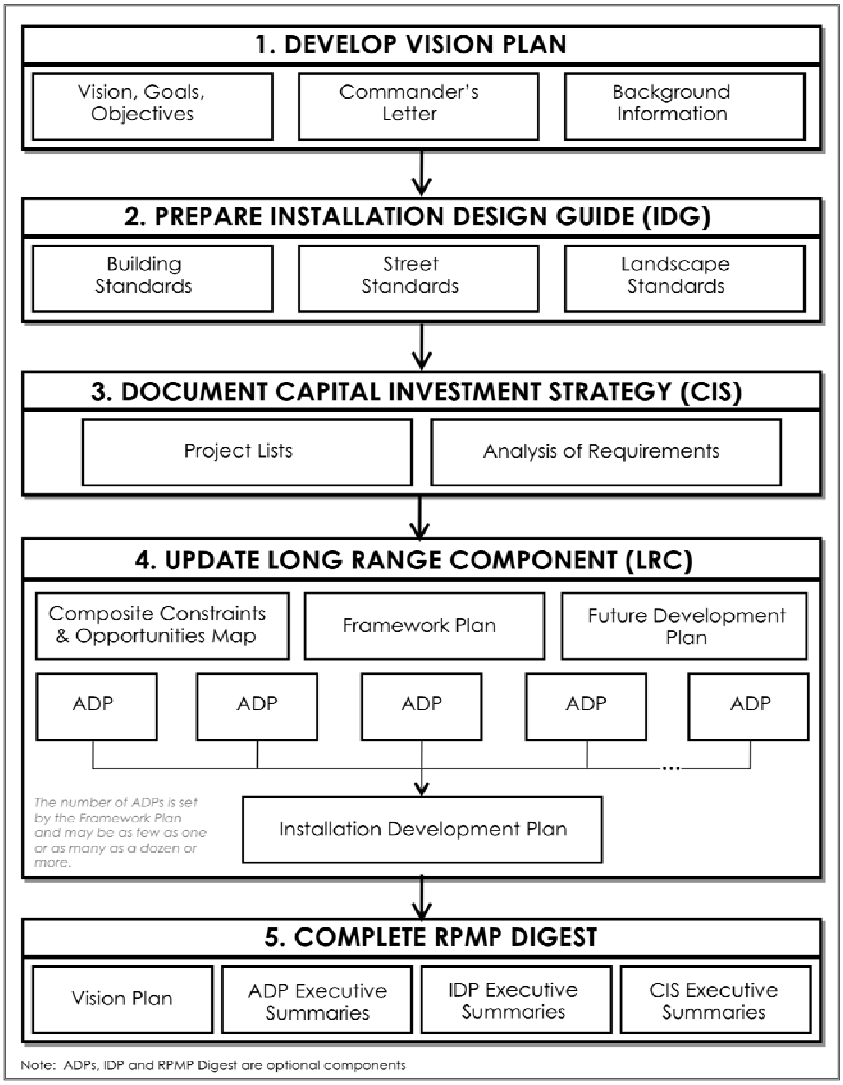

Figure 3-1. Overview of Installation Master Planning Process
(Adapted from: AR 210-20, 2005)

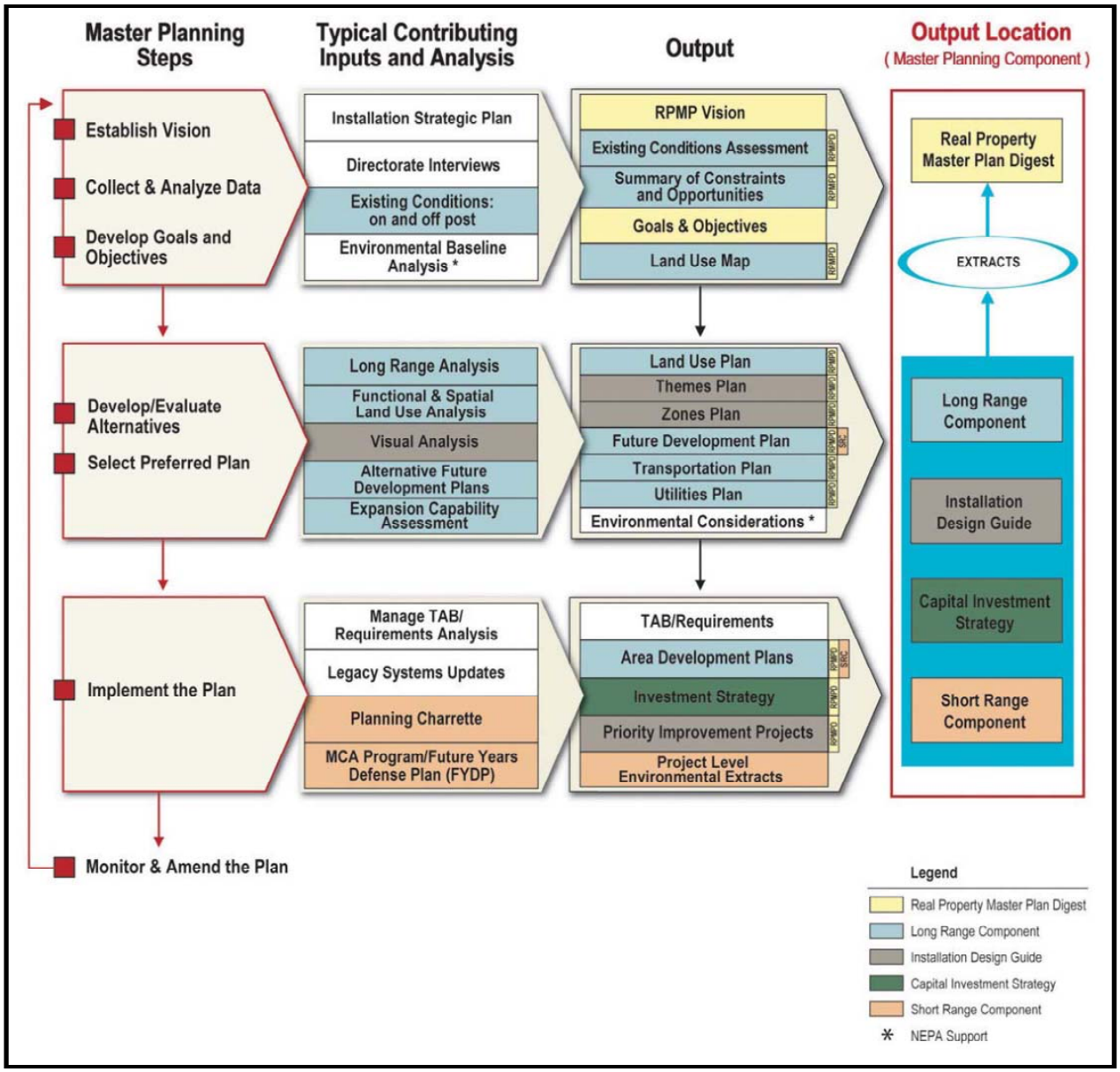

Figure 3-2. Real Property Master Planning
(Source: RPMPTM, 2008)

Figure 3-3. Scales of Master Planning
(UFC 3-210-01A, 2004)

3.2.1 Army Land Uses

For the purpose of integrating LID in the planning process and selecting LID BMPs for specific sites, Army land uses can be grouped into five categories based on similarity in land cover type (e.g. parking, open space, buildings), intensity of use, and hydrologic characteristics. This grouping allows planners and site designers to develop consistent and predictable non-structural and structural LID BMP implementation strategies for the installation. The land use categories are adapted from UFC 2-200-02AN (2005) as follows:

1. **Industrial**: Industrial sites are often highly impervious areas, such as roofs, parking, and storage areas that are densely developed with a variety of activities that potentially produce pollutants and high volumes of runoff. These may include areas for manufacturing, supply

and storage, maintenance activities, motor pools, and handling and storage of hazardous materials. Pollutants from industrial activities, such as vehicle washing and repair, are industrial activities and must be treated under separate permits and strategies. Specific land uses include:

- Operations
- Supply/Storage
- Maintenance
- Manufacturing and Production
- Research, Development, and Testing
- Utilities
- Airfield Hangers and Maintenance Areas

2. **Professional/Institutional/Community**: These land uses contain large impervious areas including rooftops and sizable areas for parking, roads, and pedestrian circulation. These facilities include both commercial services such as the Post Exchange and commissary and community services of a non-commercial nature such as the library, chapel, and craft workshops. They also include medical and dental facilities, such as hospitals, clinics, and supporting laboratory facilities. Specific land uses are:

    - Administration
    - Commercial Services
    - Community Facilities
    - Medical and Dental

3. **Residential**: Residential land uses include both troop and family housing areas. Troop areas consist of living quarters for enlisted personnel, non-commissioned officers, and commissioned officers, as well as supporting service, administrative, storage, and supply facilities related to housing. These can be detached houses with large yards, multi-family or barracks with large buildings, parking, and assembly areas, or townhouse type developments. There may be large open spaces between buildings, for assembly areas and for lower density developments. Residential also includes roadways and trails. Specific land uses are:

    - Troop Housing
    - Family Housing

4. **Ranges and Training**: Ranges and Training facilities include classroom buildings and other indoor facilities, as well as outdoor maneuver and range areas. They can have large open spaces as well as building and parking structures. These may include large impervious areas for parking and storage, cleared areas for operations, temporary and permanent roads and trails ranging from dirt to asphalt or concrete surfaces, permanent and temporary buildings and structures. A detailed description of the planning and design of ranges and training areas has been previously published (PWTB 200-1-62, 2008). Specific land uses include:

- Assembly Areas
- Bivouac Areas
- Driver Training Sites
- Drop Zones
- Maneuver Corridors
- Urban Operations (MOUT)
- Multi-Purpose Range Complex
- Parking Areas
- Secondary Roads
- Small Arms Ranges
- Tank Trails

5. **Open Space and Water**: Open space and water areas generally have much less impervious surfaces and may be used for passive and active recreation, reserved areas designated to separate incompatible uses or protect fragile ecosystems, and as a safety measure around operational or training uses. Parking and access roads may be included Specific uses include:

    - Reserved Land/Buffer
    - Recreation
    - Water Areas

The relationship between these land uses on an Army installation is important to the function and circulation for installation activities. It is also important to understand how the siting of these land uses interact with the natural environment and hydrology, both on the installation and within the watershed. Developing these relationships allow for holistic planning for LID that preserves the natural hydrology and environment while achieving the installation mission. Integrating LID BMPs on some of these land uses may be limited due to the types of activities, for example, infiltration practices may be limited on industrial land uses to avoid groundwater contamination, however, a bioretention cell with an underdrain may perform better. The following sections will describe the site planning process in seven steps for the implementation of LID BMPs to meet the requirements of EISA Section 438.

3.3 SITE PLANNING AND SITE DESIGN WITH LID

Site planning for LID involves a shift in the traditional approach for managing stormwater. When planning for a built environment, preventing increased stormwater runoff and maintaining the pre-development hydrology of the site is required by EISA Section 438. Any unavoidable increase in stormwater should be viewed as a resource that can be managed on-site with an opportunity to infiltrate the soils and/or be treated for pollutants by working with the natural site conditions, such as topography and soils. Using non-structural and structural LID BMPs through treatment trains, or in combination with conventional stormwater infrastructure when necessary, will minimize the impacts of the project on the hydrologic function of the site. Maintenance of the LID BMPs needs to be included in the parameters of the site, to ensure sustainability of the site hydrology.

3.3.1 MILCON Execution and LID

Site specific planning under the Military Construction (MILCON) process requires implementation of LID BMPs to comply with EISA Section 438. UFC 3-210-01A (Area Planning, Site Planning, and Design) and UFC 3-210-06A (Site Planning and Design) provide guidance on the site planning and design process and the "Army Standard Operating Procedure: Integrating Low Impact Development into MILCON Process" provides guidance on integrating LID into the early stages of project development and programming. Figure 3-4 illustrates the site planning and design process.

The site planning process begins with planning charrettes and the development of DD Form 1391 or DA Form 4283 where project requirements, site location and costs for the project are determined and carried through to the approval process. The DD Form 1391 is a planning document used to develop project scope and associated costs to complete the project as identified in the "Primary" and "Supporting Facilities" and "Project Description" sections of the 1391. The project 1391 is completed during the Planning Charrette process and is managed by the USACE. Tab J of the 1391 should be used to identify LID related criteria including the square footage of impermeable surface being added to the project site; and a description of LID features planned for incorporation within the project and used to manage the increased runoff from the additional impermeable surface. During this early stage of project planning, LID should be identified as a project requirement, as identified in the Master Plan, IDG and/or ADP.

The Project Definition Report (PDR) is a validation of the scope of work in the DD Form 1391. The PDR is developed and completed during the project Design Charrette process and contains the data for the parametric design (15%). Paragraph 2.1.6 (Site Development/Civil) of the PDR describes site development features that will be used to address LID implementation for the project. A project parametric design (Code 3) consists of a Project Definition Report (PDR) and a completed ENG Form 3086 detailed cost estimate based on the scope of work in the PDR. Identifying LID requirements in the early phases of planning ensures that LID will be carried through to be included in the cost estimate and design process. Figure 3-5 identifies seven steps for optimal LID BMP selection to ensure compliance with EISA Section 438 that should be followed during the planning process from DD Form 1391 developmen through the PDR, Parametric Design and ENG Form 3086.

For a local DPW funded project using Sustainment, Restoration and Modernization program funds (O&M), the process of identifying LID requirements should be determined the same way as outlined in the Project Definition Report (PDR), paragraph 2.1.6. It is imperative that sufficiently detailed LID requirements be identified in the PDR because the 3086 cost estimate is developed to determine the project cost.

For Design-Build projects, it is important to have the installation IDG, ADP and Master Plan updated to identify installation LID policy and preferred LID BMPs for meeting EISA Section 438 requirements. The installation DPW will indicate their preference for certain LID BMPs for a project as they work with the USACE project team who will get the Design-Build project awarded. The USACE project team will identify LID features and submit a concept plan (35% design) or fully developed LID BMP design to be submitted with the RFP. The installation IDG, ADP and Master Plan can be referred to in the request for proposal that will include either the LID BMP

concept plan of full LID BMP design to contract with the Architect-Engineer firm. It is imperative that the project manager at the USACE review the AE designs to verify compliance with EISA Section 438. It is important for the project manager to provide construction oversight to ensure the LID BMPs are built correctly.

For Design-Bid-Build projects, the project design to include the full LID BMP designs are included in the bid package developed by the USACE project team. The USACE project team will design the site and LID BMPs to meet the EISA Section 438 requirements. It is important for the project manager to provide construction oversight to ensure the LID BMPs are built correctly.

The following sections will describe the seven steps in Figure 3-5 for integrating LID in site planning and design, which are to be followed concurrently with the site planning and design process for the development project.

LID Site Planning Goals

- Plan first,
- Prevent. Then mitigate,
- Manage stormwater as a resource – not a waste,
- Mimic the natural water cycle,
- Replicate pre-development hydrology where possible,
- Integrate natural systems,
- Disconnect. Decentralize. Distribute,
- Maximize the multiple benefits of LID,
- Use LID everywhere, and
- Make maintenance a site parameter.

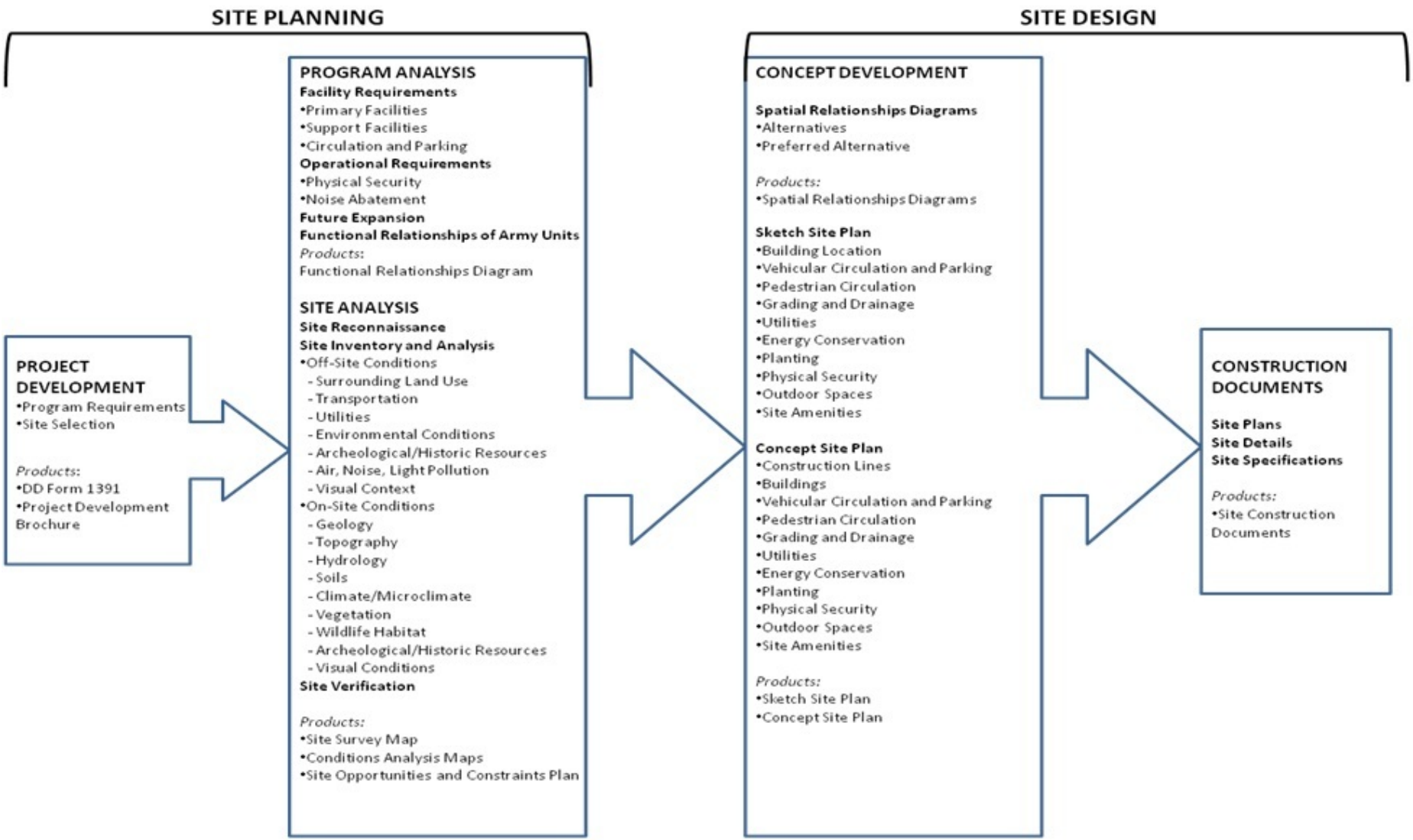

Figure 3-4. Site Planning and Design Process
(Source: UFC 3-210-06A, 2004)

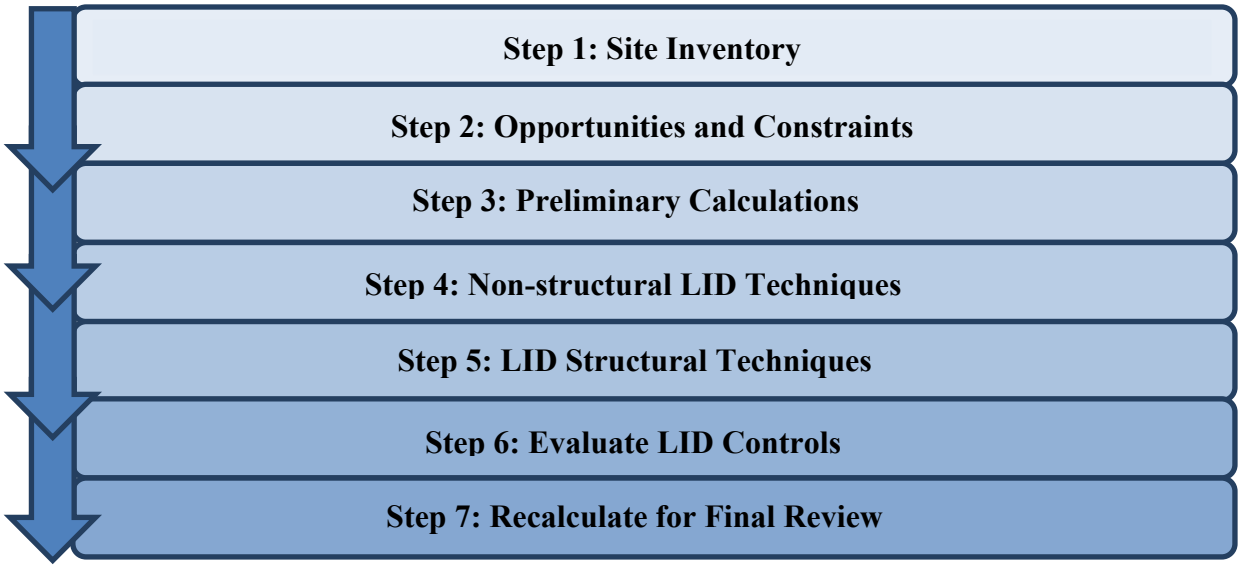

Figure 3-5. Steps for Site Planning and Design for LID

3.3.2 LID Site Planning and Design Step 1: Site Inventory

The first step to planning a site is to take a detailed inventory of what currently exists on the site and the site conditions. Incorporating LID into site design begins with a thorough assessment of the site and its natural systems which may pose challenges and/or opportunities for stormwater management and site development. Substantial guidance on the assessment of natural systems and infrastructure has been developed in UFC 3-210-01a and UFC 3-210-06a and supporting documents regarding collecting data on the natural environment, built environment, and the socio-cultural environment for site planning; in this Army LID Technical User Guide, the focus will be on collecting data with the goal of integrating LID into site planning and design.

Environmental and Man-Made Features to Consider in LID Design

- Geological Conditions
- Soils
- Hydrology
- Topography
- Natural Resources
- Land Use/Land Cover
- Facilities Infrastructure

Site conditions that influence LID BMP selection and design include geology, soils, hydrology, topography, natural resources, land use/land cover and facilities infrastructure. The site inventory should include data collection on these features, as described in the following sub-sections adapted from UFC 3-210-01a and UFC 3-210-06a, and spatial data to develop the opportunities and constraints maps in Step 2 of the LID Site Planning process. While conducting the site inventory for project planning and LID Site Planning, keep in mind that the goal is to maintain pre-development hydrology by avoiding, minimizing and/or mitigating project impacts to the hydrologic function of the site. Key environmental and man-made systems including human environment features and their importance to LID design are described below.

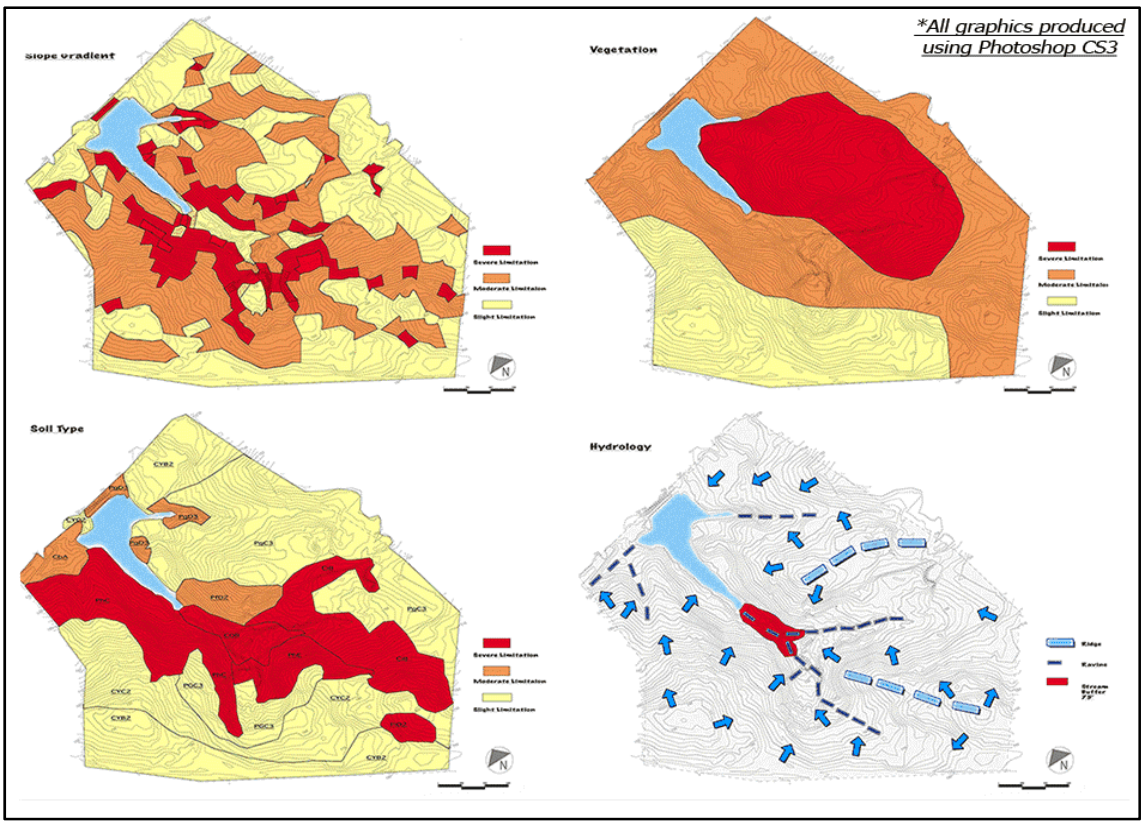

Figure 3-6. Watershed Inventory of Natural Resources
(Source: Birtice A. Garner IV, The University of Georgia)

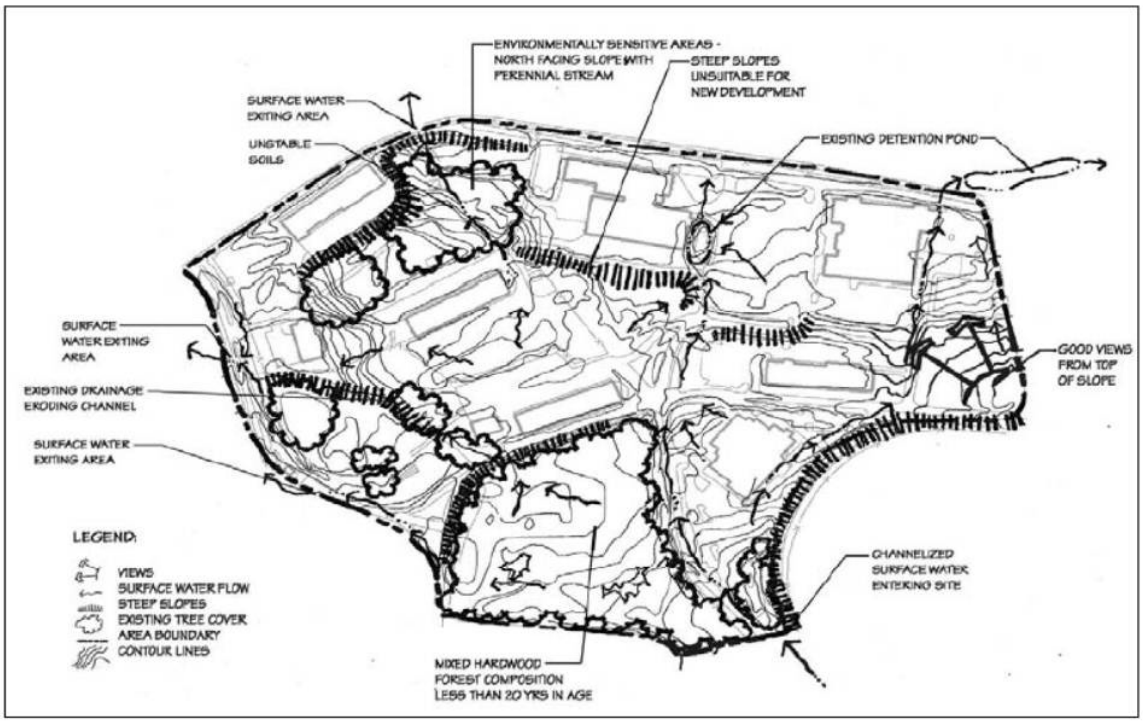

Figure 3-7. Site Inventory
(Source: UFC 3-210-01A, 2004)

3.3.2.1 Geologic Conditions

The geologic conditions of the site that should be inventoried include underlying geologic formations, depth to bedrock, substrate drainage, and areas that are sensitive to erosion from groundwater, such as limestome or Karst topography. This data can be collected from the U.S. Geologic Service (USGS) or from state resource agencies. If the project is in an area of concern (e.g. limiting formations, limestone or karst topography) field investigations, borings, and geologic assessments should be conducted. Understanding the geologic conditions of the site is important for LID site planning, as it may restrict the use of on-site infiltration – shallow bedrock will limit infiltration and karst topography or high water tables may allow for polluted runoff to enter the groundwater before sufficient filtration can occur.

3.3.2.2 Soils

The soils on the site are a key element in LID planning, as the characteristics of the soil will influence the selection and design of LID BMPs. Soils have varying infiltration capacity and permeability, which influences the amount of runoff from the site; as such soils are divided into four hydrologic soil groups (NRCS, 2007):

- **Hydrologic Soil Group A**: Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 in./hr.).

- **Hydrologic Soil Group B**: Soils in this group have moderately low runoff potential and moderate infiltration rates when thoroughly wet. Water transmission through the soil is unimpeded with a moderate rate of water transmission (0.15 to 0.30 in/hr). Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. Group B soils consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately course textures.

- **Hydrologic Soil Group C**: Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted with a layer that impedes downward movement of water; the rate of water transmission is moderate (0.05-0.15 in/hr). Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.

- **Hydrologic Soil Group D**: Soils in this group have high runoff potential when thoroughly wet due to very low infiltration rates; these soils have a very low rate of water transmission (0.00 to 0.05 in/hr). Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water impermeable layer less than 50 centimeters [20 inches] and all soils with a water table within 60 centimeters [24 inches] of the surface are in this group, although some may have a dual classification, as described in the next section, if they can be adequately drained.

During the site inventory, soils can be identified using soil surveys, which can be found on the internet at the NRCS Soil Data Mart website: *http://soildatamart.nrcs.usda.gov/* or the Web Soil Survey website: *http://websoilsurvey.nrcs.usda.gov/*. These resources provide detailed information about the soils on site, including spatial data, drainage class, ability to transmit water (hydraulic conductivity), approximate depth to groundwater, and general properties and qualities. For the purposes of LID site planning, the hydraulic conductivity and the hydrologic soil group are key characteristics, as they dictate the runoff potential of the soils on site. This needs to be considered when selecting LID BMPs that will infiltrate the natural soils, or if they will require soil amendments, addition of soil media, or an underdrain where water cannot infiltrate. Depth to groundwater must also be considered to avoid polluting groundwater from limited filtration. Once a concept plan is developed, additional borings at proposed LID BMP locations may be required to determine the infiltration rates for the design of the LID BMP.

Some of the limitations include soils with low permeability, high shrink-swell soils, or soils susceptible to frost heaving, soils susceptible to wind erosion, soils with high organic material, soils with high water tables or confining (compacted) layers, soils with high erosion potential, or soils that are unstable for grading as steeper slopes. Soils with high infiltration rates should be protected from construction activities and development because they have the ability to infiltrate larger volumes of water after development.

3.3.2.3 Hydrology

Hydrology on the site includes surface waters, such as streams and wetlands, and groundwater as well as precipitation data. It is important to understand where the site is positioned in the watershed, to consider upstream effects and potential downstream impacts from the project. In order to meet EISA Section 438, the pre-development hydrology of the site must be maintained, so understanding the existing hydrology and functions of the site is critical. The capacity and the function of the drainage infrastructure surrounding the site is also an important factor.

An inventory of the hydrology of the site should include:

- Precipitation data
- Location and functions of surface waters, including streams and wetlands
    - Drainage area – subbasins and larger watershed information
    - Flow direction
    - Interaction with groundwater
    - Surface area
    - Classification (i.e, perennial, intermittent or ephemeral stream)
    - Waterbody impairments (i.e., TMDL)
- Groundwater supplies and depth
- Floodplain areas and flooding concerns
- Drainage basin and watershed characteristics and mapping

Much of this information can be found in the installation Master Plan, the Integrated Natural Resources Management Plan, and other installation documents provided by the installation DPW. Other sources of information include National Oceanic and Atmospheric Administration precipitation data (www.noaa.gov), the US Fish and Wildlife Service National Wetlands Inventory (http://www.fws.gov/wetlands/), Federal Emergency Management Agency floodplain maps, and state and local agencies.

Planning for LID BMP selection and placement, requires an understanding of the hydrology and functions on the site and within the watershed. The LID BMPs should work with the existing hydrology, so the natural hydrology of the site is maintained and continues to function without adversely impacting existing water resources and downstream resources.

3.3.2.4 Topography

Topography on the site, and the surrounding area, strongly influences the direction of runoff across the site. Topographic data will show slopes, potential drainageways, low points and depressions where water may flow or be stored. This data may be available at the installation DPW or the installation spatial data office. If topography is not readily available on the installation, contour lines and digital elevation models (DEM) are available from USGS and state and local agencies. For detailed topography, a survey may be conducted on the site.

Understanding the topography of the site will help with the location of LID BMPs. It is best to use the existing topography and minimize grading when possible, to maintain the natural flow paths down slopes and drainageways. Placement of a LID BMP at the bottom of a slope or along a drainageway works with the natural landscape and will minimize ground disturbance and stormwater infrastructure requirements. LID BMPs such as vegetated swales, bioretention and level spreaders can and should be designed to take advantage of the existing slopes, depressions and flat open space.

3.3.2.5 Natural Resources

Natural resources on the site and in the surrounding area can play a significant role in planning for LID. An inventory of the vegetative communities and habitat areas will identify any sensitive ecological areas that may need protection. Sensitive areas could include wetlands, old growth forests, rare, threatened and endangered species habitat, riparian zones, and habitat corridors. The vegetative cover and soils on the site will influences the movement of water across the site, as vegetation can slow the runoff and aid in infiltration into the soils; this information is necessary to determine the curve number for hydrologic simulation as discussed in Chapter 4. Natural resources data can be found in the Installation Natural Resources Management Plan or by conducting a survey of flora and fauna. State and local resource agencies can also supply information regarding rare species and sensitive habitats.

Natural areas can provide buffers to streams and wetlands, dissipate stormwater runoff sheetflow, and provide pollutant removal benefits from runoff. Protecting these natural areas coincides with several non-structural LID BMP, and can provide great ecological and hydrologic benefits at minimum costs.

3.3.2.6 Land Use/Land Cover

Existing land use and land cover on and surrounding the project site play a significant role in the movement of stormwater across the area. *Land use* refers to the activity, economic purpose, intended use, and/or management strategy placed on the land cover type(s) by human agents or land managers. *Land cover* refers to the characteristics and surface cover of Earth's surface, as represented by vegetation, water, bare earth, impervious surfaces, and other physical features of the land. Areas of forested lands and open areas will slow the movement of water and allow for infiltration, while areas of impervious surface restrict infiltration and typically convey water to stormwater infrastructure. A change in land use on the site from pervious to impervious surface will significantly impact the hydrology of the site and the surrounding area, by reducing the opportunity for infiltration and altering the natural flow paths and velocity of stormwater. Understanding the relationship between the existing and proposed changes to land use and the hydrology of the area will allow for effective planning and implementation of LID BMPs to preserve the pre-development hydrology of the site. The cumulative impacts of land uses and changes to land use upstream of the site should also be considered to plan for changes in hydrology on a comprehensive level. Land use and land cover data may be found at the installation DPW and/or GIS office or from a state agency. Future land use and land cover changes can be determined from the Installation Master Plan.

Preserving open space and vegetated areas, minimizing grading, and maintaining existing natural drainageways and flowpaths are appropriate non-structural LID BMPs to include during the planning phases. Incorporating structural LID BMPs will work with most land uses, as there are great opportunities for LID BMPs in parking lots.

3.3.2.7 Facilities Infrastructure

Mapping of the existing facilities infrastructure, to include stormwater infrastructure, utility lines, roads, and other man-made features, are necessary to determine opportunities for LID BMPs. This map is available at the installation DPW office and/or GIS office.

There may be opportunities to retrofit stormwater infrastructure with a LID BMP or to reduce a planned conventional stormwater system by incorporating LID BMPs. Understanding the existing and proposed networks of roads and pipes, allow for an opportunity to take a comprehensive look at where incorporation of LID BMPs can create a more natural hydrologic regime on site and in the surrounding area.

3.3.3 Site Planning and Design Step 2: Opportunities and Constraints

Using all of the data collected in the Site Inventory step, maps of geology, soils, hydrology, topography, land use/land cover, and facility infrastructure can be overlayed to identify areas of opportunities and constraints for planning a development project with non-structural and structural LID BMPs (Figure 3-8). This analysis can and should extend outside of the site to include watershed and installation scale factors or influences. This data analysis process must consider and incorporate the potential for change in the hydrologic function during future development activities.

The opportunities and constraints map should consider the all of the existing physical conditions on the site, both natural and man-made, within the context of the development program. Identifying the opportunities and constraints provide the foundation for making decisions on the site layout and the location of non-structural and structural LID BMP practices. When planning the development project and integrating LID, restricting development on areas with mature vegetation and soils with high infiltration rates, and maintaining drainage patterns to those areas is an example of a non-structural LID BMP that could reduce the amount and size of structural LID BMPs and any necessary stormwater infrastructure. The opportunities and constraints map will provide a guide for the configuration of the development project and illustrate opportunities for the integration of LID. Opportunities for LID include, for example, preserving riparian buffers, using the existing topography to locate swales or bioretention, allowing for infiltration where soils permit and risk of groundwater pollution is low and retrofits to existing stormwater infrastructure and impervious surfaces. Constraints for LID include steep or unstable slopes, risks of contamination to groundwater by using infiltration associated with a shallow water table, impermeable soils that would limit infiltration, risks of flooding would influence LID BMP selection, and some ATFP requirements.

Figure 3-8 shows an opportunity and constraints map that addresses the physical features of the site. It includes recommended buffers, potential areas for development, and flow patterns that should be preserved. LID focuses on maintaining existing flow patterns and volumes, as well as buffers to protect the hydrologic function of the resource.

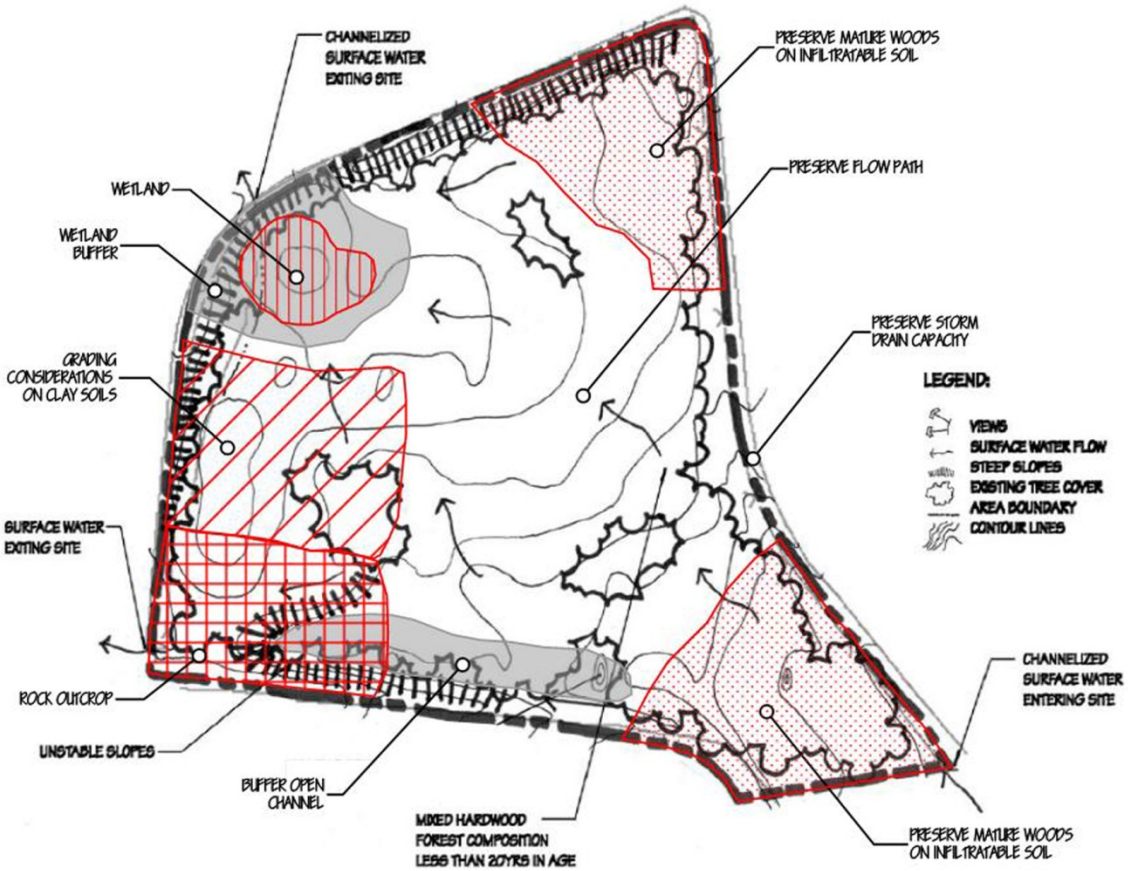

Figure 3-8. Site LID Opportunities and Constraints
(Source: UFC 3-210-01A, 2004)

3.3.4 Site Planning and Design Step 3: Preliminary Calculations

The requirements of the development project with regards to building space, parking, and other associated needs are identified during the planning charrette and DD-1391 development for the project and will direct the configuration of the site and provide an estimate of ground disturbance. As the focus of EISA Section 438 is to maintain pre-development runoff volume, runoff rate, and the temperature of runoff, the existing hydrologic conditions and the post-development hydrologic conditions must be calculated to demonstrate the difference in stormwater runoff pre- and post-development. A volume of stormwater runoff will be calculated from the hydrologic analysis using one of two options that will be the required volume of runoff to be managed on site using LID BMPs. The project engineer or a hydrologist can perform these preliminary calculations and follow them through the project as LID BMPs are incorporated.

The two options for estimating the required volume of runoff that needs to be retained on-site using LID BMPs to comply with EISA Section 438 are described in detail in Chapter 4, along with a hydrologic simulation tool to assist in the calculations. One option is to retain the runoff from the 95th percentile rainfall event. The second is to conduct a detailed hydrologic analysis of the site to

compare the pre-and post-development hydrologic conditions. Both methods require some assessment of the post-development runoff characteristics in order to determine the appropriate mix and type of LID BMPs to meet the requirements. Other federal and state regulatory requirements and infrastructure capacity requirements must also be satisfied. This may require the use of more than one method of analysis to determine the hydrologic, hydraulic, and water quality management approach for the project.

Once the initial volume requirements or pre-development conditions for the base are determined, a concept plan that includes LID strategies and techniques can be developed.

3.3.5 Site Planning and Design Step 4: Non-Structural LID BMPs

At this point in the site planning and design process, the project requirements and site conditions are known and site design can begin. Using the opportunities and constraints maps with the project requirements and the stormwater runoff volume requirements, conceptual designs can be created using non-structual LID BMPs. The method of developing non-structural site planning and design strategies is an iterative process with an objective to develop a plan with the least impact on the hydrologic function.

The opportunities and constraints map identifies sensitive environmental areas and illustrates areas to preserve. The development footprint should occur outside of stream and wetland buffers, areas with steep slopes, soils with high infiltration rates, and mature vegetation. The width and conditions of the buffers are dependent on many local and regional environmental factors, including but not limited to habitat type, soil erosion factors, and receiving waters conditions. Flow patterns and flow lengths should be maintained wherever possible. Opportunities to connect or enhance buffers and corridors should also be identified. The development area can be then be distinguished. Figure 3-9 illustrates how to use the site conditions, such as the topography, to orient development to preserve drainageways, which helps mimic the pre-development hydrology; the road and buildings are aligned parallel to the contours so that grading is reduced and stormwater runoff flows can be disconnected or sheet flow into vegetated areas. Figure 3-10 shows opportunities for non-structural LID BMPs that work with the site conditions and the development requirements for the site: riparian and wetland buffers are preserved as are existing flowpaths and mature woods with infiltratable soils. Figure 3-11 illustrates clustered development to maximize the use of space while minimizing impacts to the natural hydrology.

Planning and site design requirements, including ATFP, ASHRAE, LEED, Installation Design Guides, and Technical Manuals must also be met and incorporated into the design.

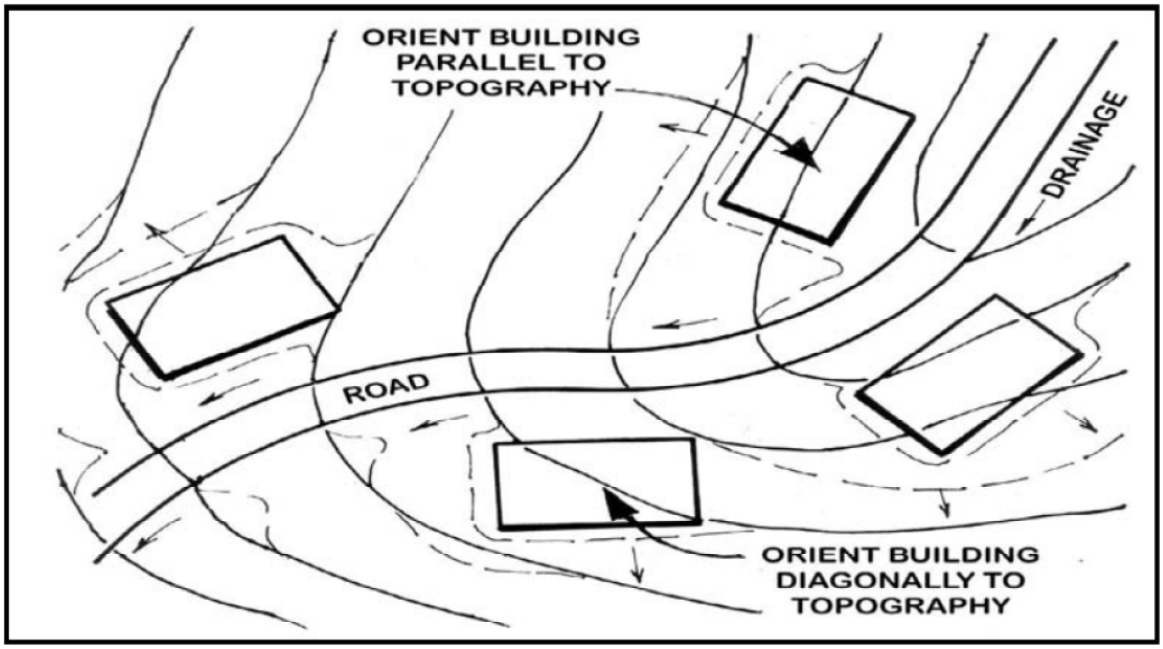

Figure 3-9. Site Concept Plan Using Existing Natural Conditions
(Source: UFC 3-210-01A, 2004)

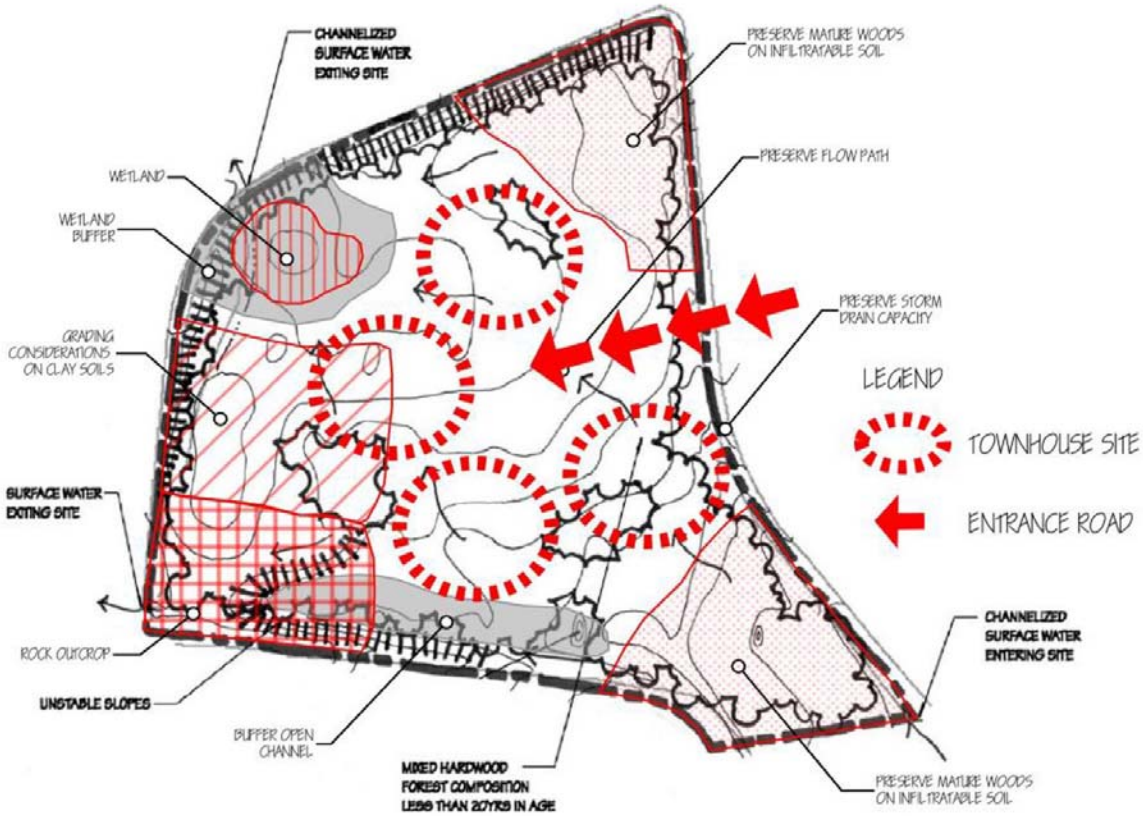

Figure 3-10. Concept Design with Non-Structural LID BMPs
(Source: UFC 3-210-01A, 2004)

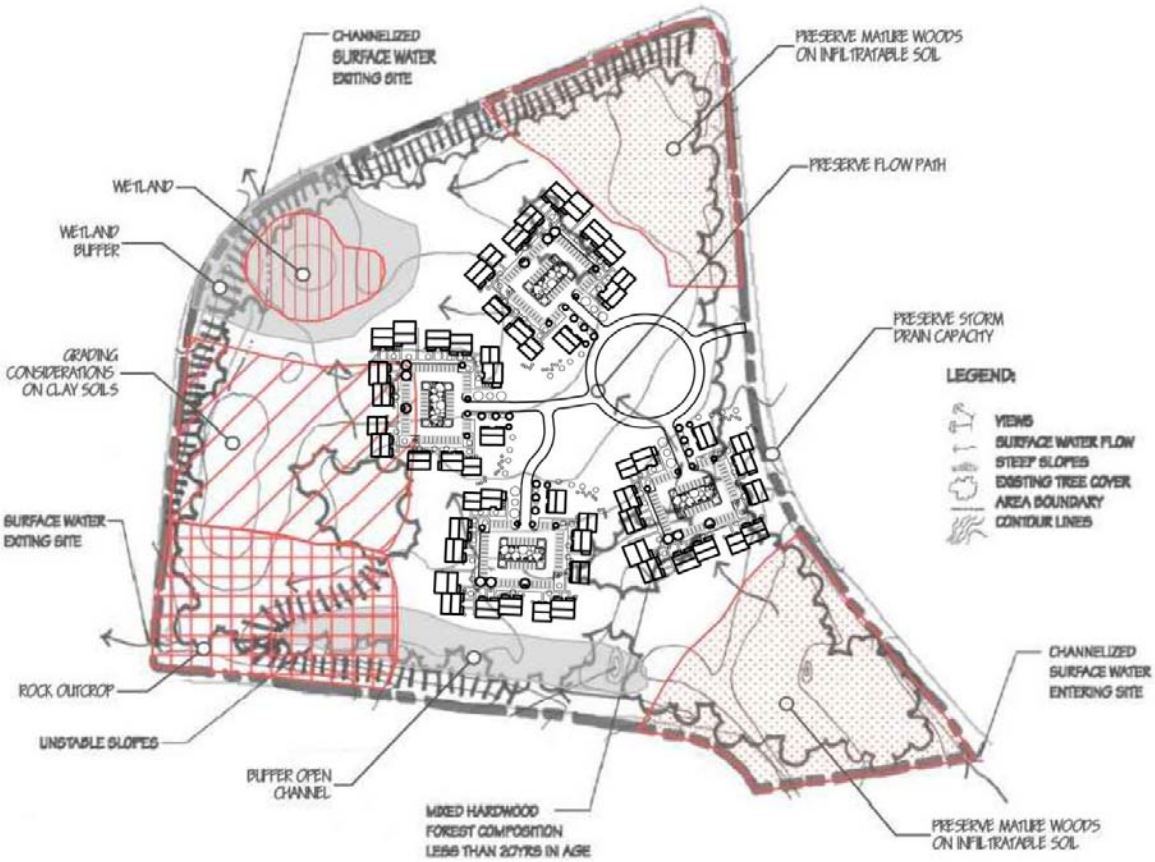

Figure 3-11. Detailed Site Design Using Non-Structural LID BMPs
(Source: UFC 3-210-01A, 2004)

3.3.6 Site Planning and Design Step 5: Structural LID BMPs

Non-structural LID BMPs can go far to maintain pre-development hydrology, though may likely not alleviate all hydrologic impacts alone. Applying structural LID BMPs on-site with the non-structural LID BMPs can provide cumulative benefits to meet the requirements of EISA Section 438. An overview of structural LID BMPs is found in Chapter 2 and design and construction specifications for the most common structural LID BMPs is found in Chapter 5. Structural LID BMPs may be combined with other LID BMPs or can tie into a conventional stormwater system.

Figure 3-12 shows a conventional stormwater management system that collects runoff into a pipe and carries it directly to a stormwater pond to store before discharging the water off-site. Figure 3-13 illustrates how non-structural and structural LID BMPs can reduce the need for portions of the conventional stormwater system by incorporating BMPs without altering the configuration of the development. Permeable pavers are used in the parking lot, bioretention is used in the parking lot island, and a bioswale is located where a drainageway may already exist. However, due to limiting factors such as a high groundwater table or soils with low infiltration an underdrain may need to be installed to collect water from the LID BMP and discharge to the stormwater system, as seen by the pipes in Figure 3-13. The use of the non-structural LID BMPs, reforestation and riparian buffer, eliminates the need for a portion of the stormwater system, the pond and pipes. The level spreader slows the flow of runoff to the natural stream as do the bioretention and permeable pavers that

discharge to the pipe; this prevents erosive forces on the stream channel and maintains the natural hydrology and aquatic habitat.

Photo 3-1 and Photo 3-2 show how a typical street within military housing can include structural LID BMPs such as permeable paving and the addition of a vegetated "bump-out" along the road, which can also include a bioretention cell or rain garden. This example shows how a street could use LID BMPs such as reduced road widths to reduce pervious surface and permeable pavements to reduce the runoff volume without impacting the land use or density of development.

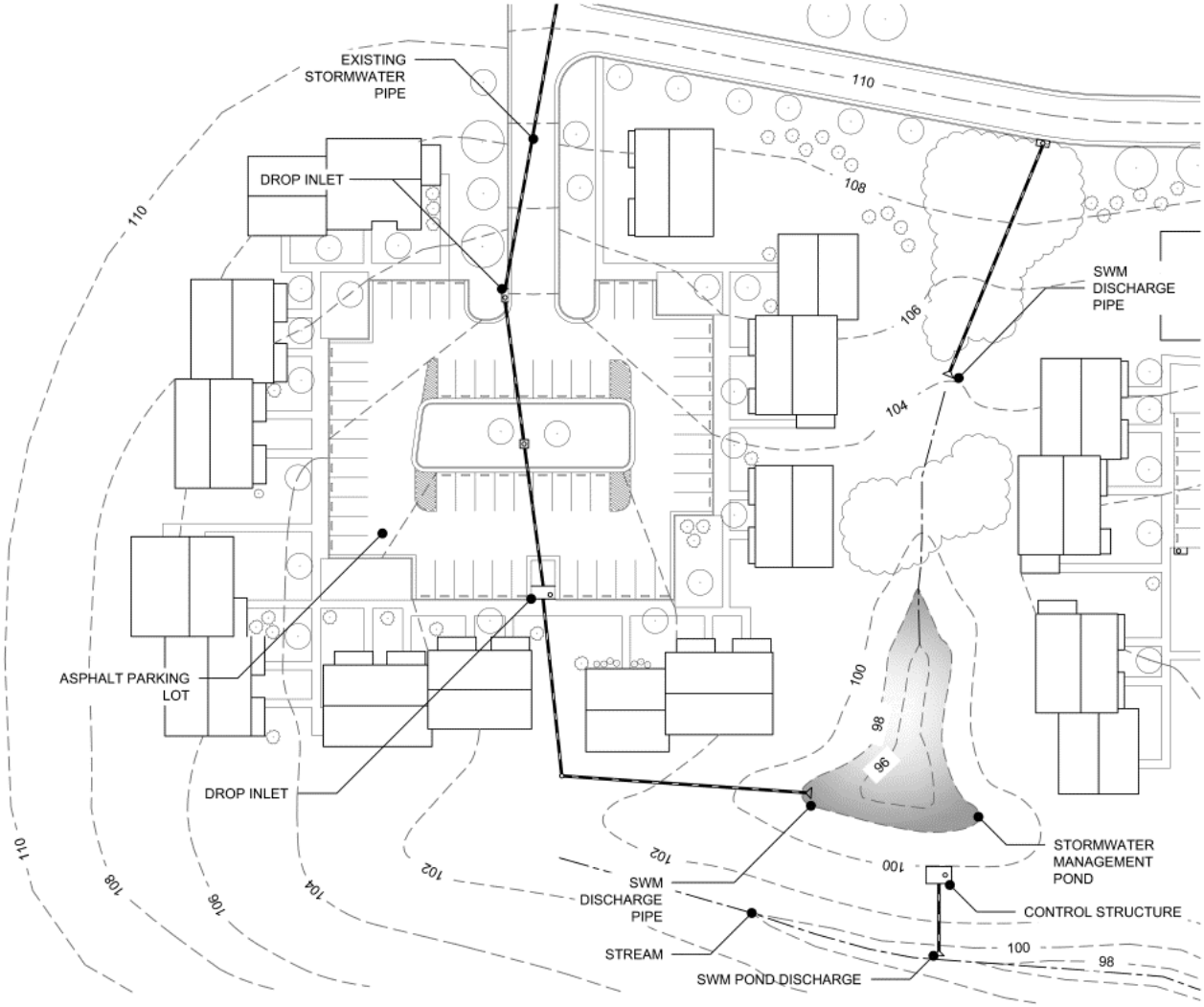

Figure 3-12. Conventional Stormwater Management
(Source: Low Impact Development Center, Inc.)

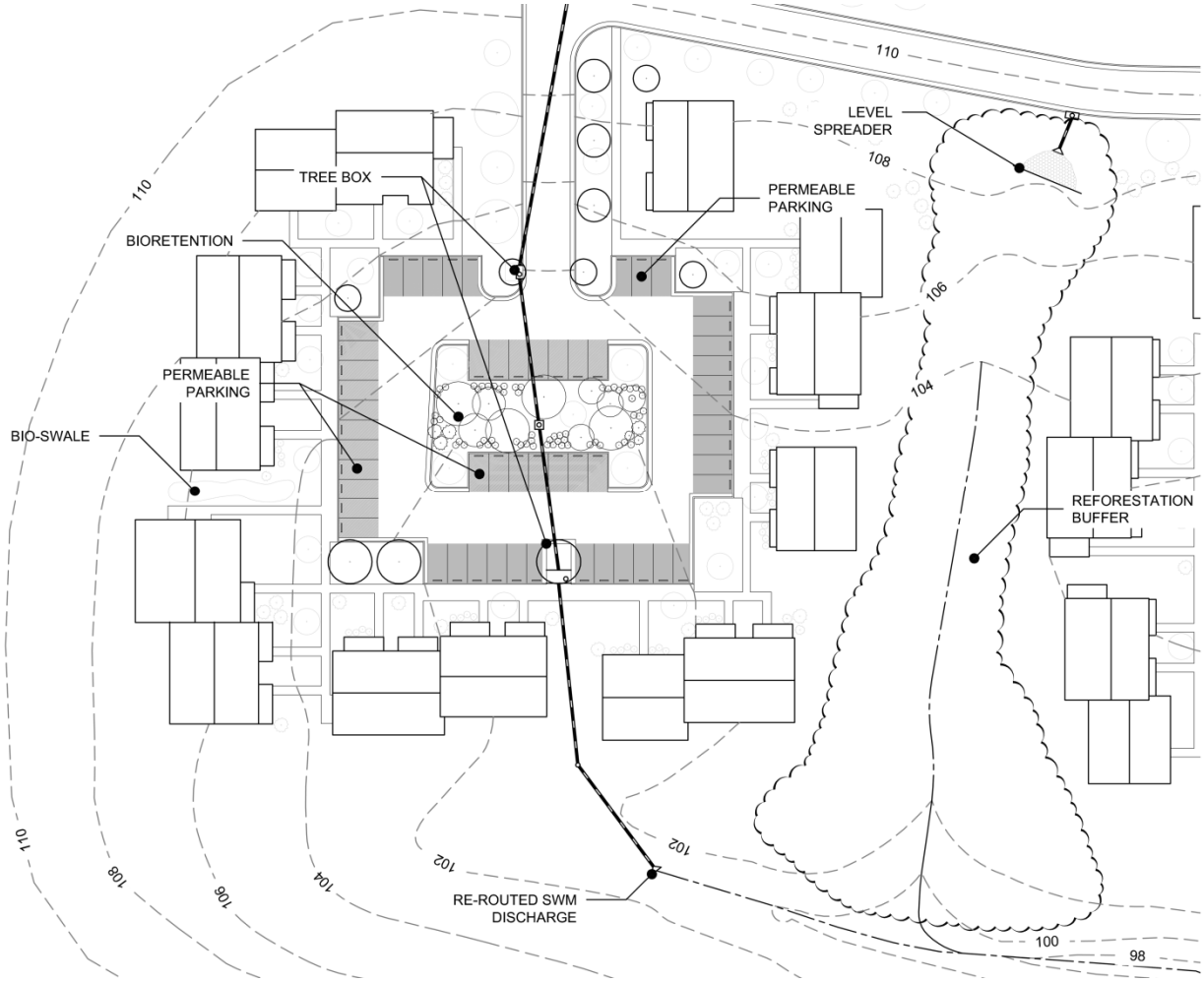

Figure 3-13. Stormwater Mnanagement with LID BMPs
(Source: Low Impact Development Center, Inc.)

Photo 3-1. Typical Street for Military Housing
(Source: UFC 3-210-10, 2004)

Photo 3-2. Street wtih Structural LID BMPs for Military Housing
(Source: UFC 3-210-10, 2004)

3.3.7 Site Planning and Design Step 6: Evaluate LID BMPs

Once the combination of non-structural and structural LID BMPs is selected and the conceptual designs are complete, the site plan must be reevaluated to determine the effectiveness of meeting the EISA Section 438 volume requirements and any other federal and state requirements. This can be accomplished through repeating the hydrologic analysis from Step 3 for the option that was selected and using the simulation provided in Chapter 4. The results of the hydrologic analysis may indicate that additional LID BMPs are necessary or larger structural LID BMPs. In some instances the volume of stormwater may be too large for the LID BMPs to manage or there may be some other limiting factors on the site. In those instances, additional end-of-pipe, or offsite stormwater controls may be required. Once the site plan team is confident that the type, arrangement and size of LID facilities is appropriate for the land use and can meet the requirements final calculations, construction documents, and be developed.

3.3.8 Site Planning and Design Step 7: Recalculate for Final Review

Once the design for the development to include non-structural and structural LID BMPs is complete, a final review to indicate compliance with EISA Section 438 is conducted. The site design process is iterative in nature and will require repeating Steps 4 through 6 using different configurations and LID BMPs to effectively maintain or mimic pre-development hydrology. The site design must also manage stormwater to meet all state and federal requirements. The final review will include documentation of the site planning and design process to illustrate compliance with EISA Section 438. If it is found that it is technically not feasible to meet the requirements of EISA Section 438, the limiting factors and basis for this conclusion must be documented.

A final site hydrologic and hydraulic report is prepared for regulatory requirements, construction review, and to document compliance with EISA Section 438, ASHRAE 189, and LEED. Final construction details, standards, and specifications are then prepared for construction and project documentation. Details for design, construction and maintenance specifications for structural LID BMPs are found in Chapter 5. It is important to note that the design specifications are clear to ensure structural LID BMPs are constructed properly to ensure function and success.