DISCUSSION

In reviewing the data, a few patterns have been recognized. It is no surprise that hydrologic events are related to the sediment and nutrient loading dynamics in the Newman Lake watershed. It is often a basic assumption that a correlation exists between the pollutant concentration and rate of flow (Manczak et al., 1971).

Data from the Newman Lake watershed have shown that indeed increased precipitation and increased runoff accounted for increased sediment and nutrient concentrations per sampling event. This is mostly true in the Thompson Creek subbasin; however, the smaller inlets demonstrate considerable variability in their response. The variability occurred in total phosphorus and suspended solids concentrations with respect to flow in the small inlets (1-10). Most notable were the results from Inlets 8 and 9. These inlets exhibited considerably higher average concentrations and exports of phosphorus and suspended solids. Inlet 8, and especially Inlet 9, also exhibited high concentrations and exports of nitrate and ammonia; although, total nitrogen concentrations for these two inlets did not reflect this. This variability can be accounted for by several factors: the size of the drainage basins, slope of the basin, land use, soils, geology and groundwater, and the combined effect with the intensity and frequency of runoff.

When flow was considered in the analysis of loading, in all instances, Thompson Creek was the largest contributing source of phosphorus, nitrate and suspended solids. The larger loading values by the Thompson Creek subbasin can be explained by the fact that it is the largest subbasin (51%), and it is also receives a higher amount of precipitation and rain-on-snow events due to a higher elevation.

For the SWCP, one of the goals was to determine current nutrient loading from creeks draining the watershed. Although, the high levels of total nitrogen, nitrate and ammonia in the outlet should also be addressed. Because of the solubility of nitrogen, large inputs of nitrogen are reaching the lake through groundwater (exfiltration), direct runoff to the lake from agricultural fields and residential areas, and septic systems. Burkett (1991) found that in piezometers located in fields surrounding the northern areas of the lake, average total nitrogen concentrations in groundwater were between 10 mg/L and 15 mg/L, depending on the location. Other sources of nitrogen inputs include the lake sediments and hypolimnion, runoff from agricultural areas, bacterial decomposition of organic matter, precipitation and algae nitrogen fixation (Horne et al., 1994). Some of these sources are reflected in the runoff from the measured creeks; however, it is clear that overall, large amounts of nitrogen have been contributed to the lake from other sources and were reflected in the total nitrogen, nitrate and ammonia concentrations at the outlet.

General land-use changes in the watershed were reflected in the GIS analyses. In terms of areal changes in forest harvesting, partial-cut logging has been the dominant type of harvesting in the watershed. The decrease in the amount of new roads in the watershed may be due to the continual management of partial-cut areas on the same sections of land for many years. In this situation, the same roads would be used during harvesting for several seasons. Rapid understory
growth, which may have made some roads undetectable in aerial photos, was another explanation for the decrease in roads in the GIS analysis. More importantly, in terms of sediment contribution, was how the roads were designed, constructed, how frequently they were used and their proximity to stream channels.

Despite Washington Forest Practices, most of the watershed lacks any significant management plan, particularly in logged areas, residential areas and developing areas. The biggest problem identified by DNR was the conditions of forest roads and private roads. Many roads lacked the proper design criteria to prevent erosion, road failure and sediment transport to the streams. Even though the GIS analysis showed a decrease in the amount of roads occurring in the watershed, the high road usage, mentioned in the DNR analysis, was not reflected in the GIS results. High road use degrades the roads and furthers the erosion process (Goldman et al., 1986). Cumulative impacts from these activities have been reflected in the sediment and nutrient loading data.

Another major disturbance which has occurred in the watershed, albeit less dramatic than logging, has been the conversion of wetlands and floodplains to agricultural use. The destruction of wetlands and floodplains in the watershed have increased the capacity of creeks to transport sediment and nutrients from the watershed to the lake. Most in-flowing channels to Newman Lake have been created or altered in the past by dredging, straightening, and the construction of levees, primarily for developing and irrigating crop and grazing lands. The reduction in the area of floodplains reduced the creeks ability to deposit its heavy sediment load on the land during peak flow conditions, therefore, this increased the transport of large amounts of sediment to the lake. There has been little change over the years in the land area generally occupied by agriculture, yet land conversion which has taken place will likely continue to influence the transport of nutrients to the lake.

In examining the loading data for total phosphorus and total nitrogen, there are still significant amounts of nutrients entering Newman Lake since the time watershed management efforts were initiated in 1976. From the 1986 data (Funk et al., 1988), it was determined that the loading rate for phosphorus was high and was contributing to the accelerated progression towards lake eutrophication. Moreover, phosphorus and nitrogen loading in 1990 and 1996 were twice that in 1986 when loading was estimated to be the least.

Considering the multiple uses and complex dynamics occurring in the watershed, it is difficult to assess the effectiveness management strategies have had on nutrient loading to Newman Lake, especially without knowing all the changes which have taken place within each of the subbasins. Despite any watershed management efforts, land uses such as silviculture, agriculture, development and ORV use have disrupted the watershed to such an extent that external nutrient loading to Newman Lake remains significant. Furthermore, lake eutrophication is progressing not only from external sources but also from internal cycling of nutrients (Funk et al., 1988). In-lake treatments have been implemented; however, if further eutrophication of Newman Lake is to be reduced, an aggressive watershed management plan must be designed, implemented and enforced.
EXISTING FRAMEWORK FOR STORMWATER CONTROL AT NEWMAN LAKE

Much can be done to prevent erosion and lake sedimentation from stormwater runoff. Specific Best Management Practices (BMP) are widely used to mitigate sources of erosion, and are usually developed for categorical activities such as road construction and maintenance, home construction, and forest practices. There are many resources available by various agencies that focus on specific activities and target control measures for those activities. The Spokane County Engineers Office has prepared “Guidelines For Stormwater Management” and provides engineers and developers with information regarding drainage requirements for land development. The Washington State Department of Ecology (DOE) has a Stormwater Management Manual, and the USDA Natural Resource Conservation Service (NRCS) has much information on erosion control.

The existing framework for stormwater control at Newman Lake basically consists of the Washington Forest Practices and the Spokane County Comprehensive Plan. The Washington Forest Practices under Chapter 222-24 WAC regulates road construction and maintenance related to logging activities. Theses practices apply to the Newman Lake watershed; however, there has been such widespread erosion and neglect by the timber industry that DNR has recently implemented more stringent and specific guidelines for this watershed (DNR, 1996). Since Newman Lake is within Spokane County, the County Comprehensive Plan and zoning ordinances provide the basic framework for managing land-use activities in the watershed. However, despite the existing resources and guidelines, few regulations have been adopted for the Newman Lake watershed to manage stormwater runoff and erosion from residential development, private road construction, and other soil disturbing activities.

DNR Prescriptions

After completion of their analysis of the Newman Lake watershed, the DNR drafted prescriptions for the protection of logging areas (including roads) and adjacent creek channels from erosion and sedimentation, respectively. These prescriptions reflect the problems associated with forest practices in the watershed which were determined to be impacting public resources. The following represents a general outline of the prescriptions developed by DNR (1996).

Logging Road Construction

- New roads will not be constructed within 200 feet of any typed water within a defined channel except for approaches to creek crossings. (Typed water refers to a classification system: generally any flowing water, ephemeral stream in a drainage which may yield flow during the wet season)
- Road construction within 200 feet of any typed water (such as approaches to creek crossings) must have the following:
  * Road grades will not be greater than 10%
  * Top soil will be placed on all exposed cut slopes
  * Cut/fill slopes and side cast material must be revegetated (naturally or artificially) within one logging/growing season
* Surface runoff control structures should include:
  1) an outslope road with rolling dips constructed every 100 feet, or
  2) a crown or inslope road with relief culverts every 100 feet.
* Roads will be surfaced with 4 inches of a non-erodible material 100 feet on each side of type 1-4 waters.
* Roads will be surfaced with 4 inches of a non-erodible material 100 feet on each side of type 5 water, or 1.5 times the length of the road fill on each side of type 5 water.

**Existing Roads**

Existing roads must meet similar requirements as the above. In addition, surface runoff may not flow across fill material or creek banks and directly into creeks. Roads constructed, or existing roads, within 200 feet of a public road must have most of the above requirements plus; a culvert must be installed in the public road ditchline, and roads will be surfaced with 4 inches of a non-erodible material on the first 100 feet of the public road approach.

**Logging**

Prescriptions for logging, yarding/skidding and skid roads were also developed. Only a few are highlighted here.

- Directionally fall and skid/yard away from all defined channels
- Where no options exist for skidding away from defined channels, temporary crossings are required
- No skid trails within 30 feet of all typed water
- Water bars to direct water on forest floor (away from streams)
- Revegetate areas with exposed soil

It is generally perceived that logging in the Newman Lake watershed is, to some degree, responsible for erosion and sedimentation which is impacting the lake. Problems in the watershed related to logging have been recognized by DNR, and as just outlined, a strategy to deal with these problems has been developed. If the aforementioned prescriptions are implemented with consistency by all parties involved, problem issues may be improved upon and the rate of sedimentation in Newman Lake may be reduced.

**Spokane County Comprehensive Plan**

Under the Spokane County Comprehensive Plan, there are several references that support the need for controlling stormwater runoff and impacts thereof. Under Waterfront Development Section 15 of the Plan, there is a clear emphasis for the development of policy that reverses some of the existing negative impacts of human activity in watersheds by emphasizing mitigation of surface runoff (Spokane County Generalized Comprehensive Plan, 1990 Amendment). Jurisdiction of the Shoreline Management Act (Chapter 90.58 RCW) which extends 200 feet from
the lakeshore, whereas the Waterfront Development Section 15 relates to primarily residential and recreational development within one-half mile of the lake shore. Outlined below are some of the more specific measures in Section 15 applicable for controlling stormwater, erosion and sedimentation around Newman Lake:

- Divert existing roadway/driveway drainage to grassed swales;
- Divert existing agricultural-related runoff to grassed swales or settling ponds;
- Divert other man made drainage to runoff facilities, to the degree possible, and reduce surface runoff pollutants to improve water quality over what exists now;
- Manage surface water runoff quantity as much as possible in the watershed area landward; and
- Reduce erosion.

It is also suggested that development approvals should be conditioned to require that a professional engineer prepare a surface water drainage plan for proposed stormwater control facilities. The engineer must certify (for a specified storm event and frequency):

- The volume of existing stormwater runoff generated on the proposed development site;
- The volume of runoff generated by the development improvements such as buildings, roads, driveways and other impervious surfaces;
- An estimate of off-site drainage that passes through the development site;
- A drainage facility design that is capable of removing silt and other pollutants from surface water runoff.
- Later, that the facility has been built as designed and as conditioned with the projects various approvals.

With a general understanding of the county's plan and policy for the control of stormwater runoff and after careful examination of the current literature, specific guidelines and recommendations can be produced for the Newman Lake watershed. This SWCP is intended as a long-term management strategy for improving lake conditions, and results from implementation may not be immediately noticed. Subsequent sections discuss BMPs and structural improvements for controlling runoff, erosion, sedimentation, and general strategies for improving lake water quality.
WATERSHED STORMWATER MANAGEMENT GUIDELINES FOR CONTROLLING RUNOFF, EROSION AND SEDIMENTATION

INTRODUCTION

Of all the water quality parameters, sediment is the major polluting agent in the world. In terms of volume, it exceeds all other sources of pollution combined; however, given the nature of the pollutant it can be more dramatically changed than any other water characteristic (Satterlund and Adams, 1992). It should be noted that natural causes of erosion cannot be controlled, and that some erosion and sedimentation will always occur. Human activities such as logging, road building, development and agriculture can be addressed to minimize accelerated erosion (Urbonas and Stahre, 1993).

The results aforementioned illustrated the correlation between runoff, total suspended solids and total phosphorus with respect to location in the Newman Lake watershed. These relationships have important implications for which types of preventative actions should be recommended and where they should be placed. In the context of spatial allocation of preventative measures, the Washington Forest Practices and Spokane County Shoreline Program have specified jurisdictions within the watershed, and those areas have the potential to be protected. The word "potential" is used because often enforcement measures are lacking and violations are inevitable. The remainder of the watershed remains relatively unprotected and continues to be adversely impacted, regulations notwithstanding.

Implementing a sound strategy for managing and protecting the whole watershed is necessary to achieve a reduction in nutrient loading. In addition to the Washington Forest Practices and the County Shoreline Program, policy which incorporates land-use planning, erosion control ordinances and other water quality protection measures needs to be developed, implemented and most importantly, enforced. In developing this policy, BMPs would serve as fundamental guidelines for preventing erosion and nutrient loading and are emphasized. These BMPs include a wide range of management, planning, education, and construction activities to prevent or reduce pollution in stormwater runoff. Current practices for controlling stormwater pollution are typically designed to the maximum extent practical (MEP) considering the extent of the pollution, the pollution source, and the technology available to treat it (CH3M Hill, 1996). The practicality of a technique also considers cost/benefit issues.

The following section discusses various techniques to help control water quality in stormwater runoff, specific to the Newman Lake watershed, and outlines several BMPs that have been used successfully in other watersheds. General site considerations and effectiveness of BMPs are also discussed. Erosion control measures, specific to logging activities in the Newman Lake watershed, have been set forth by DNR and have already been discussed.
GENERAL STORMWATER RUNOFF BMPs

BMPs are management or design criteria adopted for area wide application and are deemed cost-effective and environmentally sound in achieving desired goals on a permanent or temporary basis. Time, funding, design constraints, and site limitations are considered when recommending BMPs. There are generally two types of BMPs - structural and non-structural. Other elements of BMPs include method of treatment and the temporal effectiveness. Optimally, several approaches and types of BMPs are often used in achieving the desired level of erosion, sediment and stormwater control.

Non-structural BMPs

Non-structural BMPs comprise a wide range of options: for example, source control programs, public education, habitat enhancement, tax incentives, land-use controls, and acquisition of development rights. As a result of the Newman Lake Watershed Plan (NLWPC, 1992), non-structural BMPs were developed and implemented on a limited basis. Examples of non-structural BMPs are listed below:

- **Ditch/Swale maintenance**: Remove blockages to flow in grassed ditches and remove vegetation as necessary. Mow grass in swales each fall before die-back occurs.
- **Infrastructure maintenance**: Remove sediments from existing catch basins and detention tanks on a regular basis to maintain significant reductions in pollutant loadings.
- **Citizen hot-line**: Establish a hot-line that enables citizens to directly report spills and dumping of hazardous substances into the surface water system of the lake. Publish and post phone numbers in highly visible places.
- **Public Education and workshops**: Establish annual meetings for the purposes of informing and educating the public of problem issues and collaborate on finding solutions.
- **Seasonal publications**: Disseminate informative publications among new residents, as well as annual newsletters with information about watershed and lake issues to all residents.

Structural BMPs

Structural BMPs consist of swales, biofiltration ponds, detention basins, and essentially any changes or additions that could be made to the exiting runoff path or stormwater conveyance system for preventing erosion, collecting sediment, or removing nutrients. Other structural BMPs that focus specifically on erosion include mechanical stabilization of oversteepened slopes, drainage controls, and permanent vegetative erosion controls. Structural BMPs can be subdivided into the following categories (EPA, 1978):
- **Swales and Ditch Conversions**: These grassed percolation areas, or waterways, prevent erosion and promote infiltration of runoff on a permanent basis. Similar methods include the use of vegetative filter strips, buffer strips, and riparian vegetation buffer strips. These types of controls are relatively inexpensive and effective at removing suspended solids and phosphorus if designed and maintained properly.

- **Temporary sedimentation controls**: Includes filter berms, filter fences, straw bale sediment barriers, impervious berms, and temporary sediment basins. These methods are used for temporarily controlling sedimentation from on-going construction activities and short-lived disturbances (less than ½ year). After this time period, they should be replaced by other permanent methods.

- **Permanent sedimentation controls**: Includes wet biofiltration ponds, dry biofiltration ponds, buffer strips, and detention basins. Most of these methods usually occupy large areas and are designed for efficient removal of suspended sediments and dissolved nutrients. For upland areas where other control measures fail, filtration ponds and detention basins are capable of capturing large amounts of sediments. Long-term maintenance is required for these control measures.

- **Drainage controls**: Includes berms, dikes and gutters, drop inlets, rock lined channels, water bars, diversion dikes, percolation trenches and sediment retention basins. These methods are used to control storm drainage and prevent overland flow from eroding disturbed soil surfaces or other highly erodible areas.

- **Mechanical stabilization of oversteepened slopes**: Includes curbs, dikes, benches, breast walls, retaining structures, slope scaling, overhang removal, and contour wattling (the packing of lengths of brush into continuous thick ‘cables’ partially buried across a slope at regular contour intervals and supported on the lower side by stakes). These methods are used to prepare and stabilize over-steepened slopes to a degree sufficient for the establishment of vegetation.

- **Permanent vegetative erosion controls**: Includes willow staking, seeding, planting, mulching, fertilization, and irrigation. These methods are viewed as the most appropriate means of stabilizing disturbed areas. If used alone, vegetative erosion methods can be expected to achieve a considerable degree of success on less severe slopes (less than 2:1) where drainage control is not a problem. However, on steeper slopes (greater than 2:1) or areas with drainage problems, permanent vegetative erosion control methods must be combined with drainage control and mechanical stabilization techniques.
Method of Treatment

Infiltration

Structural BMPs provide three basic methods of treatment: infiltration, filtration and detention/retention. Infiltration relies on the percolation of stormwater through unsaturated soil for treatment. Provided soils are permeable enough to use this type of treatment, several physical, chemical and biological characteristics and processes commonly found in soils are utilized to trap, attenuate and/or transform stormwater contaminants (CH2M Hill, 1996). The water is basically filtered before being transported to underlying groundwater. Infiltration is relatively efficient at removing contaminants in the particulate form and moderately efficient at removing soluble contaminants (EPA, 1993). The major disadvantage, depending on the loading, is the regular maintenance that is required to keep the facility operable.

Filtration

Filtration relies on vegetation or filter media to remove contaminants in the form of particulates entrained in stormwater. Filtration areas can take several forms and include the following: vegetated biofiltration swales, grassed percolation areas, vegetated filter strips, sand filters, peat filters, or compost filters (CH2M Hill, 1996). Although the maintenance requirements are not high, they are often better suited as a pretreatment stage in treating stormwater.

Detention / Retention

Detention is a means of temporarily impounding stormwater to trap eroded soil and allow it to settle out of solution. Detention facilities could be in the form of wet biofiltration ponds, dry ponds, constructed wetlands and sediment basins. Although larger in size than other types of treatment, the impoundment of the stormwater in wet biofiltration facilities and constructed wetlands also allows time for chemical and biological processes to break down soluble contaminants (EPA, 1993).

Source Control vs. Downstream Control

Source control simply refers to controlling stormwater in upland areas before the erosion potential becomes large. There are several advantages to source control: facilities are small and require less land; sites are dispersed thus benefiting lakes receiving runoff from many tributaries, and; the burden on downstream facilities is lessened. Most source control programs utilize infiltration and percolation type facilities throughout the watershed (Urbonas and Stahre, 1993).

Downstream control facilities are located at the downstream end of a large watershed or at the end of a subbasin within a watershed. These facilities are usually large and are in the form of a detention facility, wet biofiltration pond, dry pond, or constructed wetland. Some advantages include having fewer locations to maintain and accessibility is less of an issue (Urbonas and Stahre, 1993).
Temporal Effectiveness

The temporal effectiveness of BMPs can be divided into temporary and permanent applications. Most temporary forms of erosion, sediment and stormwater controls are directed toward intensive, short-term activities such as new home construction, road building or other soil disturbing activities. Temporary typically means less than six-months of continuous disruption (EPA, 1978). These types of controls include utilizing filter fences, filter berms straw bale sediment barriers and impervious berms. For projects lasting greater than six-months, a more permanent type of facility should be considered.

More permanent forms of BMPs applies to controlling impacts from stormwater runoff from disturbed sites for a period greater than six-months. Permanent facilities are usually designed to handle greater hydraulic fluctuations as well as greater sediment loading. These types of facilities are also designed to last a long time and incorporate maintenance plans. Examples of permanent structures include detention basins, vegetative erosion controls, drainage controls, and mechanical stabilization of slopes (EPA, 1978).

BMPs for the Newman Lake Watershed

The location and application of BMP stormwater controls are site specific and a thorough investigation of problem areas, with individual site evaluations, would be necessary for determining the appropriate control measure. Further consultation with a professional engineer is necessary to meet standard design requirements and hydraulic capacities for a given structure. The overview of stormwater control strategies and BMPs has provided the background information for selection and implementation of controls. Recommendations for stormwater controls in the Newman Lake watershed have been made based on limited field observations; however, with information gathered in the DNR report, the GIS analysis, and the 1996 water quality data results for runoff, some generalizations can be made on the applicability of BMPs throughout the watershed.

Recommended BMPs for controlling stormwater in the Newman Lake watershed are divided into four broad categories: development, road building and maintenance, general surface runoff in undeveloped areas, and perennial/ephemeral creeks. Specifics on permits, legal responsibilities, and costs are not discussed. Agricultural practices and forest practices exceeding 5,000 board feet do not apply to this discussion and are regulated under the provisions of Title 222 WAC.

Development

BMPs discussed here should apply to all new development and redevelopment in the watershed. These BMPs predominantly include the use of vegetative cover practices and structural practices where source control is the goal. Temporary vegetative cover practices may be implemented to provide cover to soils that are exposed for periods longer the 7 days but less than 6 months. Structural BMPs may be used on a more permanent basis where the generation of runoff cannot
be controlled by other means. General principles for applying stormwater controls in developing areas are outlined below (Goldman et al., 1986):

- Develop strategies for controlling runoff and erosion during the planning phase, before altering the physical setting of a drainage area.
- Prepare construction sites by establishing vegetation on vulnerable areas before work begins.
- Manage water where it naturally flows and sediment where it lies prior to development.
- Divert runoff away from denuded areas and vegetate or mulch denuded areas.
- Keep erosion and sediment control structures as close to the disrupted site as possible.
- Keep runoff velocities low.
- Time grading and construction, in terms of the wet season, to minimize soil exposure.
- Fit development to terrain and minimize length and steepness of graded slopes.
- Prepare drainageways to handle concentrated or increased runoff.
- Inspect and maintain constructed facilities as much as possible.

Road Building and Maintenance

The discussion here applies mainly to native surface or unpaved and gravel roads. BMPs most utilized for road building and maintenance are structural; however, strategies for controlling stormwater runoff from roads go beyond BMPs. The inherent design of unsurfaced roads plays a significant role in runoff generated. Given the extent of degraded road conditions in the watershed, considerable attention should be focused on road construction and maintenance. In addition to strategies described here, it is important to develop BMPs that are consistent and compatible with DNR prescriptions that relate to roads in the watershed. Recommendations and general strategies for controlling stormwater from roads (native surfaced and unpaved), in the form of BMPs, are outlined below (Satterlund and Adams, 1993):

- Good road drainage is the most important design consideration.
- Construct the least amount of road to meet management needs.
- Roads should lay as gently as possible upon the land, rather than being cut and blasted out of it.
- Locate roads in the most stable parts of the watershed and minimize the length and width.
- Roads should be strategically placed by taking advantage of ridgetops, natural benches and terraces to avoid excessive soil exposure.
- Roads should be located to prevent the sediment they produce from reaching streams.
- Road stream crossing should be kept to a minimum and cross at right angles and, with the maximum extent practical, utilize constructed fords, culverts and bridges.
- Cut and fills should be balanced to expose the least amount of soil to erosion.
- Slope moisture should be controlled.
- Unnecessary travel on dirt roads should be avoided when wet to prevent creating ruts that channel surface water into erosive concentrations.
- Vegetative cover should be encouraged on unsurfaced roads.
Where erosion occurs and prevention is difficult, construct sediment basins to trap the sediment.
Unneeded roads should be retired from use and 'put-to-bed' whenever and wherever possible.

Undeveloped Areas

In undeveloped areas in the watershed, stormwater control is best achieved by implementing non-structural BMPs which focus on prevention. Although roads exist in undeveloped areas, the previous section addresses BMPs for roads in more detail. The general strategy in undeveloped areas is to encourage treatment of runoff by means of infiltration, filtration and detention. It is also recommended that general land-use management utilizes measures which will protect the soil surface from exposure, compaction and displacement (Brooks et al., 1991). General principles for applying stormwater controls in undeveloped areas are outlined below:

- Retain existing hydrology and vegetation wherever feasible.
- Encourage grass and herbaceous cover on exposed soils.
- Avoid logging and heavy grazing on steep slopes.
- Lay out roads and trails so that runoff is not channelized on steep, susceptible areas.
- Apply erosion control techniques on agricultural fields and promote infiltration.
- Conduct any skidding of logs on steep slopes in upward directions to counteract drainage concentration patterns.
- Locate livestock-watering facilities or access to minimize runoff production to water bodies and degradation of streambanks.
- Promote infiltration of water into the soil as much as possible to increase the chances of sustaining plant growth and to reduce the erosive effects of surface runoff.
- Leave riparian trees to provide a continuing source of roots and large debris to maintain resistance to channel downcutting.

Perennial / Ephemeral Creeks

Perennial and ephemeral creeks and tributaries in the watershed serve as transport mechanisms for sediment. In addition to non-structural BMPs which focus on preventative measures for protecting the stream bank from erosive forces, there are many structural BMPs which can serve to eliminate or reduce the amount of sediment creeks transport. A downstream control strategy, utilizing structural BMPs on a permanent basis, is presented here. Although, source control measures and BMPs focusing on prevention are preferred methods, downstream controls are effective when source controls are insufficient in reducing sedimentation. Construction of these downstream controls greatly depends on the hydrology, site characteristics, drainage area, land availability and goals for treatment. Particular attention should be given to Inlets 8, 9 and Thompson Creek. Recommended facilities for reducing the sediment load carried by creeks are outlined below:
• **Dry Biofiltration Ponds**: These are appropriate for intermittent inlets, and other small drainages around the lake, where flows are intermittent. Potential sites include areas adjacent to Newman Lake Rd. where the road and inlets cross. Inlet 9 would be especially benefit from these structures. These locations would be necessary for easy access and maintenance.

• **Wet Biofiltration Pond or constructed wetland**: The only location where this may apply would be on Thompson Creek. In a wet biofiltration pond, a certain level of water is always maintained for plant life. Depending on the level of treatment desired, space required for this type of treatment could be 1-2% of the drainage area sub-basin (EPA, 1993). Thompson Creek subbasin is about 8,655 acres; therefore, approximately 86 to 170 acres would be needed. The most efficient location would be downstream in the fields close to the lake. Wet biofiltration has been proven to be an effective method for removing large percentages of suspended solids and nutrients from larger drainages, especially if plants (therefore nutrients) are harvested and removed from the pond on an annual basis (EPA, 1993).

• **Detention basins**: For off-site control of sediment laden runoff. Size can vary, however, sediment detention basins are typically small structures. Potential sites include areas adjacent to the main road around the lake where the road and inlets cross, especially Inlet 9. These locations would be necessary for easy access and maintenance.