CASE STUDIES OF LOCAL STRATEGIES FOR CONTROL OF NON-POINT SOURCE POLLUTION IN COLORADO (USA)

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1. Introduction

In the 1998 National Water Quality Inventory report to Congress, the State of Colorado reported that eighty-nine percent of the State's 171,000 river kilometres and ninety-one percent of the 59,000 lake hectares in the State have "good" water quality, fully supporting designated uses [1]. Maintenance of this high level of water quality is important from the standpoints of water supply, protection of aquatic ecosystems, and sustenance of industries that rely on the pristine environmental conditions for which Colorado is known. Primary sources of non-point source (NPS) pollution in Colorado include agriculture, mining, construction, and urban runoff, with much of the lake impairment in the State attributable to the latter two sources [1]. NPS pollutant sources from construction and urban runoff have the potential to increase dramatically in coming years due to population growth and associated urbanisation; population is projected to be nearly two times 1990 levels by 2025 for the Denver metropolitan area and for the State as a whole [2].

While non-point source discharges are regulated on the Federal level through the National Pollutant Discharge Elimination System (NPDES) of the Clean Water Act (CWA) and on the State level through the Colorado Discharge Permit System (CDPS), local agencies are taking responsibility for water quality protection through local initiatives, ordinances, and development requirements. These local controls typically address many issues including:

- Wetlands protection.
- Preservation of undisturbed buffer zones adjacent to waterbodies and wetlands.
- Stream habitat preservation and restoration.
- Stormwater quality management.
- Land use and zoning restrictions, including the creation of "overlay" districts.
- Source water protection requirements, often related to public water supplies.
- Limitations on the amount of imperviousness created in a watershed.
- Special erosion and sediment control requirements.
- Threatened, endangered, rare, and sensitive species.
- Preservation of groundwater supplies.
- Minimum streamflow.

J. Marsalek et al. (eds.), Advances in Urban Stormwater and Agricultural Runoff Source Controls, 81–93.

This paper presents case studies of local initiatives, both in the Denver metropolitan area and in the mountain region, to illustrate strategies for controlling sources of NPS pollutants in the rapidly growing urban areas of Colorado as well as for minimising impacts from development in sensitive areas. Case studies include local ordinances addressing water quality and wetlands protection as well as an agreement imposing specific water quality requirements, including numeric limits, on stormwater discharges from residential development. Case studies of local ordinances include:

- Cherry Creek Reservoir Watershed Stormwater Quality Model Ordinance [3].
- Town of Silverthorne Waterbody, Wetland and Riparian Protection Regulations [4].

In addition to these case studies, the Grant Ranch stormwater quality management and monitoring program [5] is presented as a case study of a project-specific agreement for stormwater management and source control to illustrate strict water quality protection requirements driven by local concern.

2. Source Control Ordinances

2.1 CHERRY CREEK RESERVOIR WATERSHED STORMWATER QUALITY MODEL ORDINANCE

The Cherry Creek Reservoir is located in the southeastern portion of the Denver metropolitan area in Arapahoe County. The reservoir has a surface area of approximately 340 hectares and a drainage basin of approximately 1000 square kilometres. The drainage basin is largely composed of rapidly urbanising portions of Arapahoe and Douglas counties and contains a relatively small portion of El Paso County at the headwaters of the creek. Land uses in the drainage basin include considerable areas of commercial development, numerous large office parks, and the communities of Parker and Franktown. The Cherry Creek Basin is shown in Figure 1. The mean depth of the reservoir is approximately 3 metres with a maximum depth of 6 metres in the vicinity of the outlet works. The Cherry Creek Reservoir is owned and operated by the U.S. Army Corps of Engineers and is surrounded by Cherry Creek State Park, an approximately 1500 hectare multi-use recreational area. Originally, the Cherry Creek Reservoir was constructed for flood control purposes in 1950; however, once the reservoir was filled, the potential for multiple uses became evident [6].

Classified uses of the reservoir include [7]:

- Aquatic Life 1 - Warm waters that (1) currently are capable of sustaining a wide variety of warm water biota, including sensitive species, or (2) could sustain such biota but for correctable water quality conditions. Waters shall be considered capable of sustaining such biota where physical habitat, water flows or levels, and water quality conditions result in no substantial impairment of the abundance and diversity of specifies [8].

- Recreation 1 - waters that are suitable or intended to become suitable for recreational activities in or on the water when the ingestion of small quantities of water is likely to occur. Such waters include but are not limited to those used for swimming, rafting, kayaking and water-skiing [8].
- Agriculture - waters that are suitable or intended to become suitable for irrigation of crops usually grown in Colorado and which are not hazardous as drinking water for livestock [8].
- Water Supply - waters that are suitable or intended to become suitable for potable water supplies. After receiving standard treatment (defined as coagulation, flocculation, sedimentation, filtration, and disinfection with chlorine or its equivalent) these waters will meet Colorado drinking water regulations and any revisions, amendments, or supplements thereto [8].

The 1982 Clean Lakes Study identified potential for negative impacts to the reservoir's beneficial uses from eutrophication. Assessments of the reservoir's trophic state from 1992 through 1996 using Carlson's Trophic State Index (TSI) based on mean values of Secchi depth, chlorophyll a, and total phosphorus from April through October indicated that the reservoir was eutrophic [6]. As a result, phosphorus is a pollutant of primary concern in the Cherry Creek Basin.

The Cherry Creek Basin Water Quality Authority ("Authority"), a quasi-municipal corporation and political sub-division of the State established under the statutory authority of the state, is responsible for water quality in the Cherry Creek Basin. The Cherry Creek Reservoir Watershed Stormwater Quality Model Ordinance ("Model Ordinance") was developed in 1999 by the Authority for the following stated purpose:

> *To provide substantive requirements to control the quality of stormwater runoff in the Cherry Creek Basin from private and public property and to reduce the loads of contaminants reaching Cherry Creek and the Cherry Creek Reservoir in furtherance of health, safety, and general welfare in the Cherry Creek Basin. This model ordinance applies to both construction and post-construction development. The recommended stormwater quality Best Management Practice (BMP) requirements set forth in this model ordinance...are necessary to reduce and maintain non-point source phosphorus loads below their load allocation, in accordance with Total Maximum Daily Load ("TMDL") set forth in the Cherry Creek Control Regulation...and the water quality requirements delineated in the Cherry Creek Basin Water Quality Master Plan...*

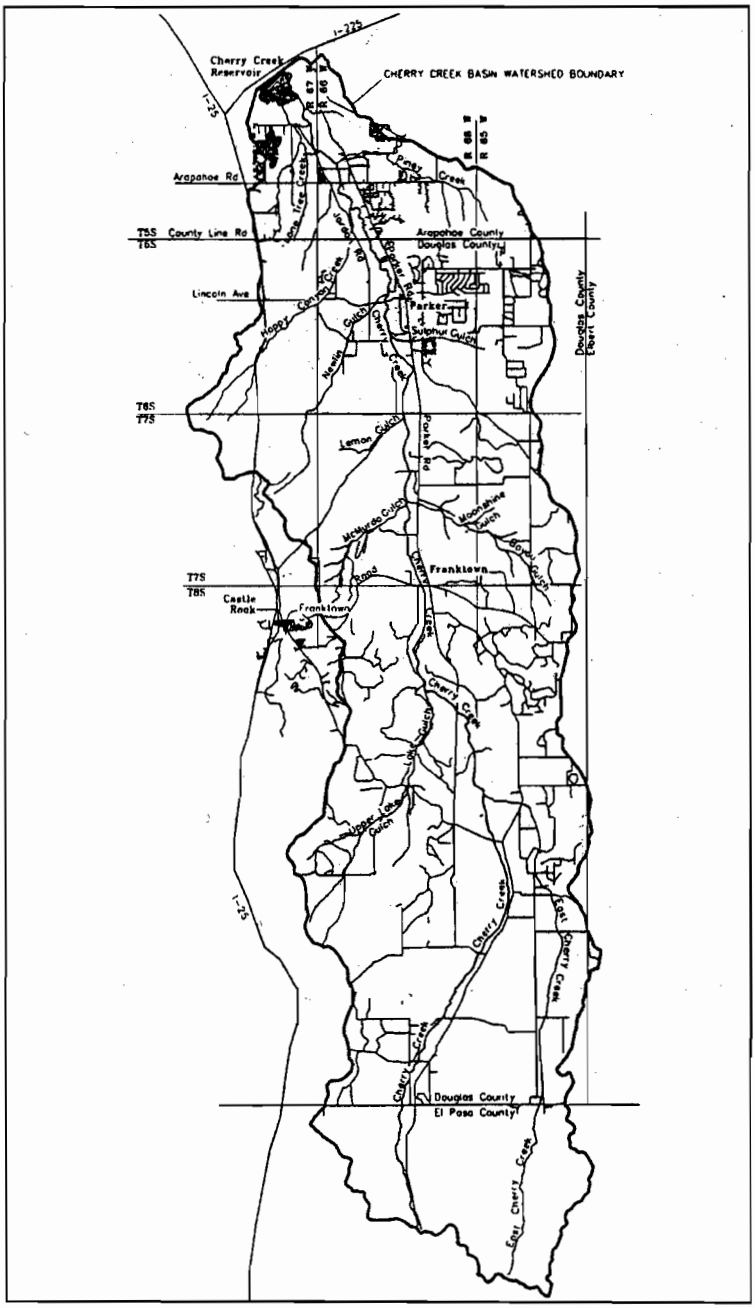

Figure 1. Cherry Creek Basin

The Model Ordinance seeks to control NPS pollution in the basin through regulation of land disturbing activities and requires that municipalities, counties, and other governmental entities with jurisdiction over land use in the basin adopt the BMPs and policies set forth in the Model Ordinance. The Model ordinance requires adoption of temporary (construction) and permanent BMPs for land disturbances including grading, cutting and filling, building, paving, and other anthropogenic activities that change the natural cover or topography of the land surface. Under the Model Ordinance, the owner of a development project is required to submit an application and receive approval for any land disturbing activities. The owner must prepare a site-specific plan for stormwater quality control, meeting the BMP requirements specified in the Model Ordinance. The Model Ordinance specifies requirements for construction BMPs and permanent BMPs and additionally contains specific requirements for industrial and agricultural activities and land disturbances occurring in stream preservation areas. Stream preservation areas include the reservoir, Cherry Creek State Park, drainage and discharge to the park within 30 metres of the park boundary, lands within the 100-year flood plain of Cherry Creek, and land overlying the Cherry Creek alluvium.

Individual home construction is exempted from the application and approval requirements of the Model Ordinance provided that the land disturbance is less than 0.4 hectares, the home is not a part of a larger development by the same owner, and sediment entrapment BMPs including silt fence, filter strips, sediment basins, and/or straw bale barriers are implemented on-site.

A major component of the ordinance is the requirement of a Construction BMP (CBMP) Plan. The CBMP Plan must include:

- A narrative description of the construction project.
- Construction schedule, including implementation of BMPs.
- Detailed descriptions and locations of BMPs and justification that planned BMPs will satisfy Model Ordinance criteria.
- Site map and drawings showing the area of disturbance; existing and proposed topography; areas of excavation, grading, and fill; and locations of proposed BMPs.
- Characterisation of site geology and soils.
- Inspection and maintenance procedures, including access considerations and site-specific inspection log. Inspection is required after installation of any construction BMPs, after any runoff event causing erosion, and at least once a month. Inspections must be documented, and inspection logs must be maintained on-site.

Land disturbing activities are to be accomplished in a way that satisfies requirements of six categories of pre- and during-construction BMPs specified in the Model Ordinance. Pre-construction BMPs must be implemented before any land disturbing activities begin, while during-construction BMPs for disturbed areas must be implemented within 14 days of soil disturbance. Categories of BMPs that must be included in the CBMP Plan include:

- Category 1: Phasing of Construction (pre-construction) - construction activities must be scheduled to minimise the amount of soil that is exposed at a given time, and areas of disturbance larger than 40 acres may not remain exposed for longer than 30 days.
- Category 2: Reduction of Runoff Flows to Non-erosive Velocities (pre-construction) - runoff flows up-gradient of disturbed areas must be diverted around disturbed areas, and runoff velocities across disturbed areas must be limited to less than 0.6 metres per second (non-erosive velocity) over bare areas. BMPs include swales, diversion dikes, terracing and contouring, slope drains, and/or check dams.
- Category 3: Protection of Drainageways from Erosion and Sediment Damages (pre-construction) - to prevent sediment from disturbed areas from entering drainageways and to keep runoff flows from eroding drainageways, BMPs including waterway crossing protection, inlet protection, outlet protection, and/or temporary diversions must be applied.
- Category 4: On-site Retention of Sediment (pre-construction) - sediment entrapment measures including silt fence, filter strips, sediment basins, and/or straw bale barriers are required to prevent accelerated soil erosion, impede sediment movement, and reduce off-site transport of sediment. Vehicle tracking control must also be provided, including plans for daily maintenance.
- Category 5: Stabilisation of Exposed Soils (during-construction) - areas that will remain exposed and/or inactive for more than fourteen days must be stabilised by mulching; seeding; tackifer application; use of erosion control mats, blankets, and nets; and/or surface roughening.
- Category 6: Revegetation of Disturbed Areas (during-construction) - temporary and permanent revegetation of disturbed areas are required within 14 days of temporary or permanent cessation of construction. Temporary revegetation is required for areas that will be exposed during any growing season prior to completion of construction, and permanent revegetation is required for disturbed areas that will be exposed for two-or more years or indefinitely.

In addition to a CBMP Plan, the Model Ordinance requires the development of a Permanent BMP (PBMP) Plan to be submitted in two phases: (1) a preliminary phase defining the nature of the development and proposed permanent BMPs and (2) a final phase providing more in-depth discussion of concepts identified in the preliminary PBMP Plan and design details for BMPs. Requirements of the PBMP Plan include:

- Narrative description of development project and map showing location of proposed development.
- Map showing drainage area; area of disturbance; existing and proposed topography; areas of excavation, grading, and fill; and locations of proposed BMPs.
- Characterisation of site geology and soils.
- Discussion of relationship to regional and basin drainage and stormwater quality plans.

- Detailed description, design criteria, location, and operation and maintenance requirements for BMPs including description of how BMPs satisfy water quality capture volume (WQCV), pollutant removal, and maintenance requirements of the Model Ordinance.
- Schematics of proposed BMPs (preliminary PBMP Plan).
- Maintenance and inspection protocols for BMPs and commitments for maintenance from responsible agencies/owners, including dedication of any necessary easements for maintenance access.
- Detailed design drawings including size, location, specifications, and technical details for all permanent BMPs (final PBMP Plan).
- Schedule for construction and operation of BMPs (final PBMP Plan).

Permanent BMPs are required to provide a WQCV designed to capture and treat the 80th percentile runoff event in accordance with the Denver Urban Drainage and Flood Control District's Drainage Criteria Manual, Volume III [9]. BMPs in the model ordinance consist of detention measures including:

- Extended dry ponds - 40-hour drain time for WQCV with additional 20% of WQCV provided for sediment accumulation.
- Wet ponds - 12-hour drain time for WQCV.
- Constructed wetlands basins - 24-hour drain time for WQCV.
- Porous pavement detention - 6-hour drain time for WQCV plus 2-inch surcharge storage volume for WQCV from adjacent areas.
- Porous landscape detention - 12-hour drain time for WQCV with additional 20% of WQCV provided for sediment accumulation.
- Sand filter detention - 40-hour drain time for WQCV.

The use of BMPs in combination is encouraged, as is the use of regional facilities serving multiple development projects. Recommended combinations of BMPs include the use of detention measures (described above) in conjunction with wetland channels and grass swales. Design depth requirements for channels are dictated by the two-year runoff event and the degree of detention provided by the channel varies from 6- to 12-hours depending on the detention provided up-gradient of the channel.

While the Model Ordinance contains provisions that are, in many respects, congruous with requirements for a stormwater discharge permit under the State's CDPS system, the Cherry Creek Basin Model Ordinance provides a more refined level of regulation for several reasons. The Model Ordinance regulates a wider spectrum of development projects by excepting only individual home construction projects disturbing less than 0.4 hectares. CDPS stormwater permits are currently required for land disturbing activities disturbing 2 or more hectares (under Phase II of NPDES, this threshold will be lowered to 0.4 hectares, but development projects below this threshold will not require a permit). In addition, the Model Ordinance provides a greater degree of regulation by requiring review of CBMP Plans. A CDPS stormwater permit requires development and implementation of a Stormwater Management Plan (SWMP); however, there is no process for review. Finally, the Model Ordinance

provides a greater level of detail than regulations on the State level by specifying design criteria for BMPs.

2.2 TOWN OF SILVERTHORNE WATERBODY, WETLAND AND RIPARIAN PROTECTION REGULATIONS

The Town of Silverthorne is located in Summit County, Colorado at an altitude of approximately 9,000 feet. The Town is experiencing rapid growth—population has nearly doubled since 1990, and the prevalence of second homes and vacation rentals in this resort community results in considerable construction activity in the Town. There are many wetlands and streams within Town boundaries, including "gold medal" trout water (the Blue River) running through the centre of the Town.

Although Section 404 of the CWA regulates dredging and filling of waters of the United States, including wetlands, the Town Council concluded that the Federal wetland permitting program did not provide adequate protection for local wetlands, lakes, and streams, primarily because the Section 404 regulations did not directly address the need for buffer zones—setbacks from the edges of wetlands and waterbodies. As a result of the local desire for a higher level of wetland and waterbody protection and provision of buffer zones, the Town of Silverthorne enacted Waterbody, Wetland and Riparian Protection Regulations, Ordinance 1999-1 [4] in 1999.

The intent of these regulations is:

> *... to protect the vital beneficial functions and values of wetlands and water areas within Silverthorne. This is to be accomplished by requiring that a permit be obtained for development activities in wetlands and water areas, and associated buffer areas, and that, as a part of this permitting process, the Town will review disturbance permits and mitigation plans. A critical element of this process is the determination of the buffer area boundary, which will vary from 25 feet [7.6 metres] to 125 feet [38 metres] depending upon the presence of site-specific features and the use of best management practices. It is intended that the buffer width will equal what is necessary to protect the wetlands and water areas from significant adverse impact arising form activities within the buffer and that applicants will be encouraged to reduce the width of the buffer through appropriate best management practices. It is anticipated that where an applicant includes best management practices, the width of the buffer will be decreased below the maximum, and that where these practices will fully mitigate the impact of development within the maximum buffer upon the wetlands or water area, the buffer will be reduced to the minimum of 25 feet [7.6 metres].*

Since the Silverthorne regulations specify a buffer between areas of development and wetlands, waterbodies, and riparian areas that can vary in width from 7.6 metres to 38 metres, determining the required width of the outer buffer zone for a specific development project is critical. To accomplish this, the Silverthorne regulations identify twelve criteria for determination of the width of the variable-width buffer zone. These criteria account for well-documented functions of wetland/waterbody buffer zones including reduction of sediment and other pollutant

loads to wetlands and waterbodies, attenuation of runoff rates and volumes, provision of wildlife habitat and diversity of vegetation, groundwater recharge, and soil stabilisation. Where BMPs are utilised, the width of the outer buffer may be reduced. To determine the width of the outer buffer zone, the following twelve criteria are applied [4]:

- Riparian Area Boundaries - the outer buffer zone must be coincident with the outermost boundary of riparian areas.
- Threatened and Endangered Species - the outer buffer zone will be established at least 7.6 metres to 30 metres from the outermost boundary of occupied functional habitat for plant and animal species listed by the State or Federal government as threatened or endangered.
- Wildlife Mitigation Corridor - in areas where there is a demonstrated wildlife migration corridor (as identified by the Colorado Division of Wildlife) an outer buffer zone of 7.6 metres to 30 metres will be required.
- Fens - where fens are present, an outer buffer of 30 metres will be required.
- 100-year Flood Plain - the outer buffer boundary must be coincident with the outermost boundary of the 100-year flood plain.
- Steep Slopes - where there is a slope of 20 percent or more within 38 metres of and draining to wetlands or waterbodies, an outer buffer width of 30 metres will be required; where there is a slope of 30 percent or more with a vertical height that exceeds 3 metres within 38 metres of and draining to wetlands or waterbodies, an outer buffer width will be coincident with the area of the slope within 38 metres of the wetland or waterbody.
- Erodible Soils - where there are soils with a Natural Resource Conservation Service (NRCS) "k" factor of 0.25 or greater, the outer buffer zone must be coincident with the area of such soils within 38 metres of the wetland or water body.
- Unstable Stream Banks - the outer buffer zone must be at least 7.6 metres when horizontal or vertical degradation of stream banks exceeds natural levels.
- Hazardous Materials - a minimum outer buffer of 30 metres is required when proposed use of property presents a special hazard to water quality resulting from storage, handling, or use of hazardous or toxic materials, chemical fertilisers, or pesticides (residential uses are excepted).
- Stormwater Permit - when the proposed land use of the property requires a commercial or industrial CDPS permit, a minimum outer buffer of 30 metres is required.
- Impervious Area - an outer buffer of 30 metres is required when any one-acre area within the potential buffer area will have an imperviousness of 40 percent or more.
- Poor Vegetative Cover - an outer buffer of 15 metres is required if vegetative cover is less than 30 percent for any 0.5-acre area within 38 metres of a waterbody or wetland area.

These twelve criteria provide a sound technical basis for the ordinance and are fundamental to its success. Another strength of the ordinance is the fact that the Town

solicited, considered, and integrated comments from the development community in developing the ordinance.

From a practical standpoint, the ordinance has had a significant impact on planning of development projects, the design and review process, and construction practices in the Town. The 3-Peaks Golf Course/single family residential development project in the Town serves as a good example of application of the ordinance. The 235-hectare development consists of an 18-hole championship golf course, clubhouse, and associated course maintenance facilities and 397 residential units. There are many wetlands on the site located as pockets spread over the development parcel. Development of the parcel is further constrained by steep slopes in many areas. To-date, the developer has prepared three detailed Disturbance Permit Applications (DPAs) to demonstrate compliance of project phases with Ordinance 1999-1. These DPAs have included lot-by-lot assessments of potential adverse impacts to buffer zones and adjacent wetlands and waterbodies and have provided detailed mitigation measures and BMPs to reduce the width of the variable outer buffer. Planned individual building pads, driveways, roads, and other lot and infrastructure features have been moved or otherwise altered to protect buffer zones and/or compensate for impacted buffer zone functions. Through careful planning, the total area of wetland disturbance for the 235-hectare site is less than 0.25 hectares, which will be compensated for by mitigation at a 2:1 ratio. The developer has frequently met with Town staff in the field to discuss compatibility of the proposed development with the requirements of the ordinance.

3. Grant Ranch Stormwater Agreement

The Grant Ranch development is a large single-family residential development in the western Denver metropolitan area in Littleton, Colorado. A portion of the Grant Ranch development falls within the watershed of the Bow Mar Reservoir. The Bow Mar Reservoir is owned by the community of Bow Mar, a relatively affluent municipality of approximately 900, which utilises the reservoir for swimming, fishing, boating, and other beneficial uses. Classified uses of the reservoir include [7]:

- Aquatic Life 1, Warm
- Recreation 1
- Agriculture

The portion of the Grant Ranch development proposed within the Bow Mar Reservoir watershed included approximately 200 homes. This proposal raised concerns among the residents of Bow Mar as to the potential for adverse impacts to Bow Mar Reservoir from runoff from the residential development. These concerns were addressed in negotiations between the developer and the Bow Mar Homeowners, which culminated in a March 1997 Stormwater Agreement [5]. The Stormwater Agreement required the developer and the metropolitan district serving the Grant Ranch to maintain advanced erosion and sediment controls during construction and to implement permanent structural and non-structural BMPs following the completion of construction.

Numeric criteria were established to gauge compliance with the terms of the agreement for both construction and post-construction phases of the development. During construction, the developer was required to meet a total settleable solids discharge limit of 2.5 mg/L/hr. Post-construction discharge limitations were more extensive, addressing parameters including:

- Phosphorus - Total Phosphorus and Dissolved Orthophosphate
- Nitrogen - Total Nitrogen, Nitrate, and Nitrite
- Chemical Oxygen Demand
- Total Suspended Solids
- Fecal Coliform
- Chloride
- Total Recoverable Cadmium, Chromium VI, Copper, Lead, Manganese, and Zinc
- Oil and Grease
- Ethyl Benzene
- Toluene
- Glyphosate
- Malathion

Numeric criteria were set based on a number of factors including established State and Federal water quality standards [7,8,10], performance studies of similar treatment systems in the Denver metropolitan area [11], and values from the national literature. Where existing technical guidance was not sufficient for establishment of numeric criteria for a parameter, the agreement provided for establishment of criteria based on water quality data collected during the initial years of monitoring of the system.

The criteria for these parameters are required to be met under both dry and wet weather conditions, and compliance is assessed based on a total of eight sampling events, two wet events and two dry events during the periods of March to May and June to September, respectively. Wet weather events that are used to gauge compliance with the agreement correspond to the more frequently occurring, runoff producing storms with rainfall between 2.5 and 12.7 millimetres. Fully automated sampling stations, equipped with modems, raingauges, and automatic sample collection and flow measurement equipment, have been established at the site to collect the samples necessary to assure compliance with the agreement.

To meet the during-construction discharge limitation of 2.5 mg/L/hr for settleable solids, the developer utilised BMPs including:

- Three large sedimentation basins.
- Conventional erosion and sediment control measures including straw bales, silt fence, and inlet protection.
- Source control construction practices including "Good Housekeeping" measures.
- An innovative system by which treated runoff from the sedimentation basins was pumped to the top of a meadow and released to flow as sheet flow through the meadow. This treatment system provided treatment through infiltration of stormwater and filtration of sediments as the sheet flow passed through the meadow.

The performance of the treatment system during construction was excellent, with only one incident of non-compliance with the numeric limit, which corresponded to a storm event with a frequency of approximately one in twenty-five years. The construction phase of the project ended in the fall of 1999.

To meet the strict criteria for post-development conditions, the developer utilised a combination of structural and non-structural BMPs. The developer and design engineer opted to utilise BMPs in series, with initial treatment provided by three extended dry detention ponds followed by secondary treatment in a wetland/water quality pond. A plan view of this treatment system is shown in Figure 2. A design storm corresponding to the 80th percentile annual event was used to determine the WQCV. Extended dry detention basins were designed to drain the WQCV over a 40-hour period and the wetland/water quality pond had a design residence time of 24 hours, resulting in a 64-hour residence time for the system for the WQCV. The Stormwater Agreement included a commitment from the metropolitan district serving Grant Ranch and the Grant Ranch Homeowners to maintain these BMPs. Nonstructural BMPs specified in the agreement include collection and disposal of lawn clippings; restrictions on the use, storage, and disposal of herbicides and pesticides; limits on the use of sand, salt, and other de-icing agents for snow and ice control in the winter; and vegetation management practices.

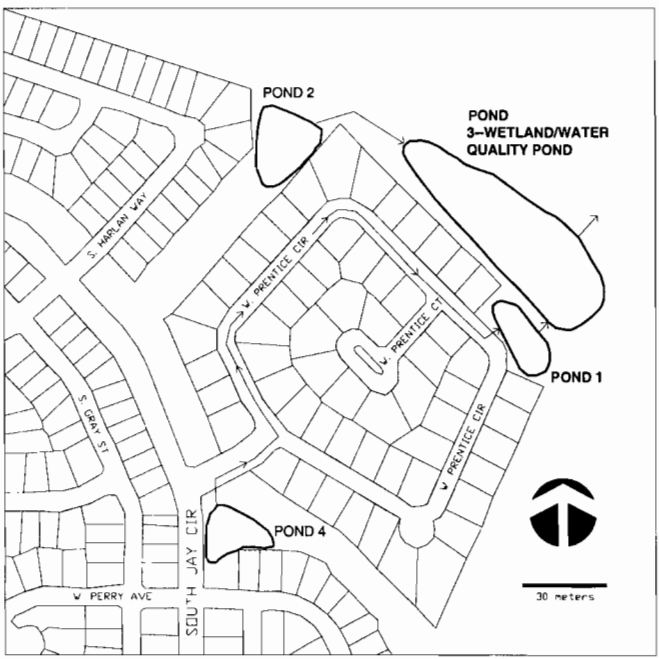

Figure 2. Permanent BMP Treatment System for Grant Ranch

4. Conclusion

Local regulations and agreements for protection of water quality and control of NPS pollution are becoming increasingly common. These ordinances and agreements are, in effect, forms of non-structural BMPs designed to prevent and reduce pollution and protect water quality through creation of processes for planning and review, establishment of requirements for structural and non-structural BMPs, and provision of mechanisms for assuring compliance.

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