Horsley & Witten, Inc.
Environmental Services

PURGATORY AND CRAMS COVE HYDROLOGIC ANALYSIS REPORT

August, 1999

Prepared for:

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PURGATORY AND CRAMS COVE
HYDROLOGIC ANALYSIS REPORT

I. INTRODUCTION

Horsley & Witten, Inc. (H&W) was contracted by the Charles River Neighborhood Foundation (the Foundation) to evaluate the potential for restoration of the Crams and Purgatory Coves in the Lakes District of the Charles River (Figure 1). Specific tasks conducted by H&W included 1) Collecting and reviewing existing information, 2) Delineating watersheds, 3) Identifying land uses within the watersheds, 4) Conducting a hydrologic analysis including field measurements of bathymetry and flow through the culverts, 5) Reviewing alternative restoration projects to improve water quality in the coves, and 6) Providing a written report of these tasks.

There are many issues of concern in Purgatory and Crams Coves since both coves have been heavily impacted by contamination and hydrological changes. A focused approach to improving water quality in these coves requires understanding of the issues and evaluating potential uses or benefits that may result if restoration were to be implemented. A summary of the issues and possible benefits are listed below to assist the Foundation and other stakeholders to formulate a vision or goal for restoration of these waterbodies (Table 1). Once the Foundation decides upon a restoration goal, a more thorough analysis can be done to determine the feasibility of restoration.

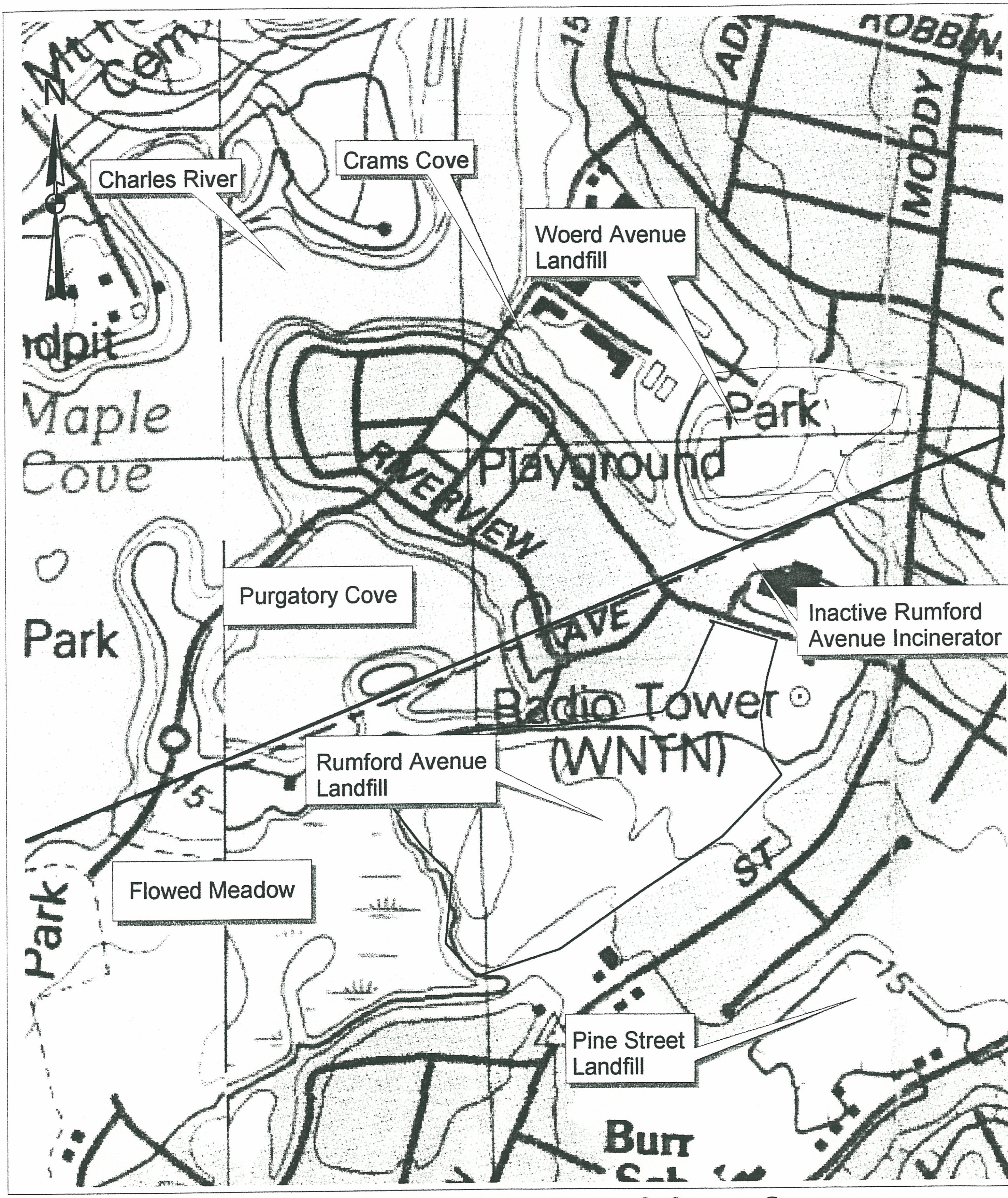

Figure 1. Locus Map - Purgatory & Crams Coves

Last Revision Date: July 21, 1999
MassGIS, USGS Topo
Prepared for The Charles River Neighborhood Foundation

200 0 200 400 Feet

Table 1. Summary of Potential Benefits and Current Problems within the Coves

Potential Benefits	Current Problems
Boating:	Shallow depth, excessive water chestnut growth
Motorized	Contaminated sediments are present and motorized boat traffic would resuspend sediments
Non-motor	Can use canoes presently; increased access would be desirable
Improved fishing & fish habitat:	Poor flow, low oxygen, warm water, contamination
Swimming:	Contaminated sediment and water; unappealing appearance, excessive water chestnut growth
Scenic views:	Unappealing; debris (Crams Cove)
Habitat "improvement":	Poor circulation, low oxygen, filling in, contaminants, debris (Crams Cove), excessive water chestnut growth

II. REVIEW OF EXISTING INFORMATION

Purgatory and Crams Coves are part of the larger Lakes District formed when flashboards were placed in the Moody Street Dam in the Charles River at Waltham, downstream of the coves, circa 1836 (Metcalf & Eddy, 1975). Crams Cove is the smaller of the two, with a surface area of 2.08 acres. It is located in Waltham, but its watershed lies within both Newton and Waltham. Purgatory Cove is approximately 13.8 acres in surface area. Purgatory Cove is located in the cities of Newton and Waltham. Both coves are shallow, approximately 3 to 4 feet in depth in Purgatory Cove and approximately 5 feet in Crams Cove. Both coves are connected to the Charles River via two culverts, Purgatory through a 15-foot culvert and Crams through an 18-foot culvert.

In terms of water quality, these waterbodies are currently designated by the state of Massachusetts as Class "B" waters. The Class "B" classification designates these waters as habitat for fish, other aquatic organisms and wildlife, and for human recreation. The water quality parameters for this standard are listed in Table 2 (Massachusetts Surface Water Quality Standards, CMR 314 4.00).

History of Water Impacts

Previous studies of environmental conditions in the coves provide valuable background information for assessing impacts and possible restoration of Purgatory and Crams Coves. A 1975 report by Metcalf & Eddy, Inc. prepared for the Metropolitan District Commission (MDC) focused upon Purgatory Cove. Nelson and Klein (1996) studied both Purgatory and Crams Coves. Camp, Dresser & McKee (1996) analyzed contaminants in Purgatory Cove as part of the site study for capping of the Rumford Avenue landfill.

Report to the Metropolitan District Commission on Water Quality in Purgatory Cove

The Metropolitan District Commission (MDC) initiated a study of the water quality in Purgatory Cove (Metcalf & Eddy, 1975). The study included a field survey to measure dissolved oxygen and temperature, and analysis of subsurface sediments. Leachate from the adjacent Rumford Avenue sanitary landfill and cove surface water was analyzed for contaminants.
Field surveys done in 1974 indicate that depth readings of the bottom topography of the cove were virtually flat with an average depth of 3 feet. Dissolved oxygen measurements in the cove indicated low to moderate amounts

Table 2. Massachusetts Division of Water Pollution Control Applicable Class B Surface Water Standards - Charles River Basin

Dissolved Oxygen	Not less than 5.0 mg/l
Temperature	a. Shall not exceed 83° F; in lakes and ponds the rise shall not exceed 3°F in the epilimnion (based on the monthly average of maximum daily temperature). b. Natural seasonal and daily variations shall be maintained.
pH	Shall be in the range of 6.5 through 8.3 standard units and not more than 0.5 units outside of the background range.
Fecal Coliform Bacteria	Shall not exceed a geometric mean of 200 organisms per 100 ml in any representative set of samples nor shall more than 105 of the samples exceed 400 organisms per 100 ml.
Solids	These waters shall be free from floating, suspended and settleable solids in concentrations and combinations that would impair any use assigned to this Class that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.
Color and Turbidity	These waters shall be free from color and turbidity in concentrations or combinations that would impair any use assigned to this Class.
Oil and Grease	These waters shall be free from oil, grease and petrochemicals that produce a visible film on the surface of the water, impart an oily taste to the water or an oily or other undesirable taste to the edible portions of the aquatic life, coat the banks or bottom of the water course, or are deleterious or become toxic to aquatic life.
Taste and Odor	None in such concentrations or combinations that are aesthetically objectionable, that would impair any use assigned to this Class, or that would cause tainting or undesirable taste to the edible portions of aquatic life.

of dissolved oxygen, ranging from 2.9 milligrams per liter (mg/L) to 7.5 mg/L, on October 11, 1974. The dissolved oxygen levels were lower than measurements made just outside the cove in the Charles River, which ranged from 9.3 mg/l to 9.5 mg/l, indicating well-oxygenated conditions. The MDC study in 1975 found that the Class B standard for dissolved oxygen was violated in Purgatory Cove. Soil borings were taken in the cove itself and on land adjacent to the cove, and two observation wells were placed in the Newton Sanitary Landfill. Sediment samples indicated that the cove is underlain by dense sand and gravel covered by a soft silt and peat layer 15 to 54 feet deep.

The Metcalf & Eddy, Inc. report (1975) refers to anecdotal evidence that Brunnen Brook formerly flowed through Purgatory Cove until the damming flooded the area. Submerged tree stumps in the western part of the cove indicate that the flooding of a previously exposed area occurred sometime in the past. The report indicates that the thickest layer of silt and peat is found in the middle of the cove and thins near the edges. The original opening to the river was 80 feet in width; this was reduced by the installation of a 15-foot diameter culvert when Forest Grove Road was improved.

Water circulation between Purgatory Cove and the Charles River was measured, using a flow meter placed at the culvert opening. No measurable water flow at any depth was recorded. The Metcalf & Eddy, Inc. report concluded that there was no measurable exchange of water between the cove and the Charles River. They also concluded that the cove was too shallow for convection currents and hence had poor circulation, especially during dry weather conditions.

A hydrologic analysis was developed to examine the five sources of water that existed at the time, entering and leaving Purgatory Cove. These five water sources were:

- Direct stormwater runoff from adjacent land areas
- Direct precipitation on the cove's surface

- Stormwater collected in a 60-inch drain which emptied into the southeastern end of the cove
- The Charles River via the culvert
- Groundwater

The water budget calculated for Purgatory Cove estimates that the turnover rate of water in the cove is only once or twice during the summer months. The report assumes groundwater contributions were negligible because of the dense layer of peat and silt that exists on the bottom of the cove. Water input from the Charles River during the summer months was also felt to be negligible, unless there was a large rise in river stage, which is not likely to occur in the summer (Table 3).

Table 3. Hydrologic Budget - Purgatory Cove (excerpted from Metcalf & Eddy, 1975)

Inputs	**million gallons/year (mgy)**
Precipitation	15
Stormwater Runoff	5.2
Charles River - 6 in. rise in river stage	2.1
Stormwater 60-inch stormpipe	42.2

Groundwater samples taken from beneath the landfill were compared to cove surface water and Charles River water for contaminants. The report concluded that the groundwater under the landfill was not as significant a source of contaminants as the Charles River itself. Analysis of the bottom sediments showed cove sediments to be less contaminated than Charles River sediments, with the exception of lead.

Charles River Lakes District Survey

In August of 1996, a preliminary ecological analysis of the two coves was conducted by Atila Klein and Michael Nelson of Brandeis University. The study examined the hydrology, water quality and biology of the coves. In general, the study concluded that Crams Cove is a more stressed water body than Purgatory Cove, although both have been affected by pollutant loading. The studies indicate that both coves are experiencing eutrophication. Eutrophication is a natural process where high nutrient levels cause excessive plant and algae growth and decomposition leading to poor oxygenation and poor water quality. Cultural eutrophication is the accelerated growth of vegetation due to anthropogenic inputs of nutrients. Eutrophication is characterized by increased concentrations of nutrients, increased plant growth, and reduced dissolved oxygen levels in water which can affect fish and other aquatic life.

During the August 1996 study, Crams Cove, Purgatory Cove and the nearby Charles River had lower oxygen levels than the Massachusetts state standard for Class B waters of 5 mg/l. In addition, high fecal coliform counts were noted, an indicator of fecal matter. Since the study was conducted, a broken sewage line in Waltham, which had been leaking into Crams Cove, has been repaired. Subsequent fecal coliform testing by the Charles River Watershed Association indicated the fecal coliform concentrations had decreased below the water quality standard for swimming, which is 200 fecal coliforms per 100 mls, and had therefore improved with respect to this water quality parameter.

Nelson and Klein (1996) also studied sediment contaminants in both Coves. Figure 2 shows the locations of these sample sites. Hydrocarbons, pesticides and metals were analyzed. Both coves were contaminated with metals, pesticides and hydrocarbons. Crams Cove had higher concentrations of metals with the exception of iron. Pesticide concentrations were relatively low in both coves.

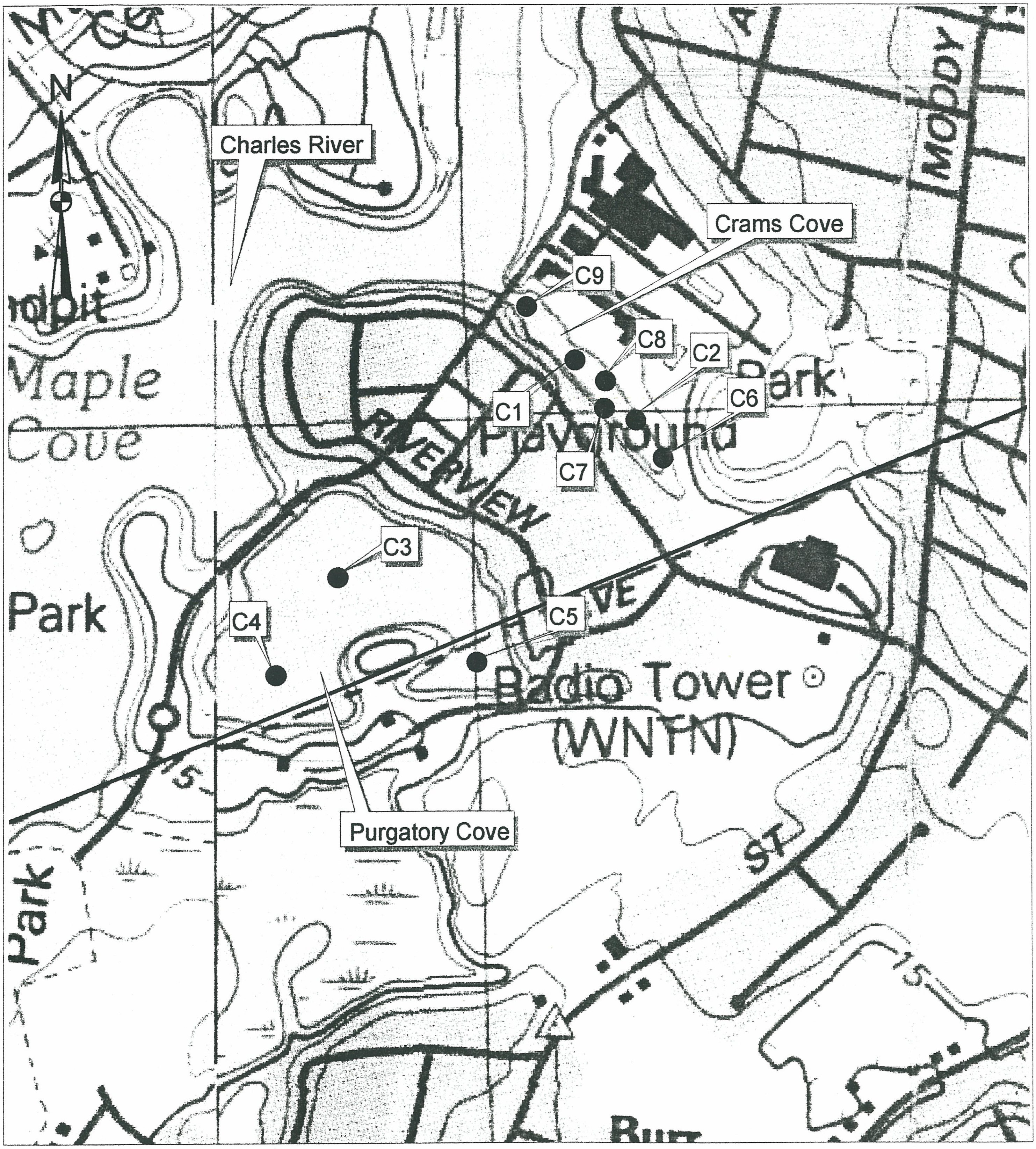

Figure 2. Locus Map - Sediment Samples (Nelson & Klein, 1996)

July 21, 1999
MassGIS, USGS Topo
Prepared for The Charles River Neighborhood Foundation

200 0 200 400 Feet

PCBs were found in Crams Cove. High levels of hydrocarbons were found on the inland side of the Cove.

Sediment data were compared to standards developed for aquatic organisms to determine biological effects of contaminants for lead and zinc. The standards were exceeded in Crams Cove, particularly at C2. The report estimates that the concentration of lead in these sediments is four times the mean of other lakes and ponds surveyed in Massachusetts. Pesticide concentrations were lower than concentrations considered to have a biological effect. In Crams Cove, silver, arsenic, cadmium, chromium, copper, lead and zinc concentrations in sediment were equivalent to concentrations determined to have low to moderate biological effects.

The report recommended further hydrologic analysis including bathymetry and flow data and that a year-long study of nitrogen and phosphorus concentrations in the water column and sediments be conducted. In addition, the report recommended that a more comprehensive study of the toxic chemicals in the sediments be done, and that biological toxicity testing be conducted prior to restoration.

Rumford Avenue Landfill Comprehensive Site Assessment,

Additional investigations of Purgatory Cove were done as part of the Rumford Avenue Landfill Comprehensive Site Assessment prior to landfill capping (Camp, Dresser & McKee, 1996). The Rumford Avenue landfill is located directly upgradient and adjacent to Purgatory Cove (Figure 1). The Comprehensive Site Assessment (Camp, Dresser & McKee, 1996) involved surface water sampling in Purgatory Cove, groundwater sampling beneath the landfill, downgradient sampling, and sediment sampling in Purgatory Cove.

Groundwater quality analyses indicated that contaminants including chloroform, trichlorethane, vinyl chloride, cadmium, and lead exceeded Maximum

Contaminant Levels (MCLs), which are water quality standards for contaminated sites. Surface water quality samples were also taken in the Charles River, Purgatory Cove, Flowed Meadow and at the outlet of the 60-inch drain pipe that ran underneath the landfill. Camp Dresser & McKee (1996) reported that most of the parameters met or were better than drinking water standards, and no volatile organic compounds were detected. In Flowed Meadow and Purgatory Cove, metals were detected more frequently and in higher concentrations than at the Charles River sampling site. Cadmium was detected above its MCL in Flowed Meadow and lead was above the MCL in Purgatory Cove. These samples reflect total metal concentrations in water. Total metals include both the dissolved phase of metals and particulate phases. Particulate metals tend to be less biologically reactive.

The report confirms that both Purgatory Cove and Flowed Meadow are more contaminated by metals in surface water and sediments than the Charles River itself. Flowed Meadow is upstream of the two coves and is part of the Charles River. Identifying the source(s) of contamination is difficult due to the fact that the Pine Street landfill is hydrologically upgradient from the Rumford Avenue landfill. Contaminated groundwater could have traveled from either site or from other sources in the Charles River.

An historical perspective can be useful in analyzing the significance of individual sources of pollution. An historical timeline summarizing local events that may be affecting water quality in the coves is given in Table 4.

III. WATERSHED DELINEATION AND LAND USES

H&W used Massachusetts Geographic Information System (Mass GIS) contour datalayers to plot surface watershed areas for the coves. Based on these surface contours, the surface watershed area for Purgatory Cove is approximately 40 acres. The surface watershed area for Crams Cove is approximately 21 acres (Figure 3).

Table 4. Historical Timeline

c.1836	Dam at Moody Street Lakes District formed, including Purgatory and Crams Coves
Date Unknown	15 ft culvert replaces 80 ft bridge at inlet-outlet to Purgatory Cove
Dates Unknown	Woerd Avenue landfill in Waltham operational (awaiting report)
c.1930 -1963	Pine Street landfill in Newton operational
1966-1996	Rumford Avenue landfill operational, Brunnen Brook culverted below landfill
1967-1974	Rumford Avenue incinerator operational
1975	Metropolitan District Commission contracted Metcalfe & Eddy, Inc. to prepare a report on improving water quality in Purgatory Cove
1988	Rumford Ave incinerator smokestack demolished
1995	CDM begins preparing comprehensive site exam and remediation of the Rumford Avenue Incinerator site
1998	Rumford Avenue landfill capped and 60-inch drainpipe removed and diverted to Flowed Meadow

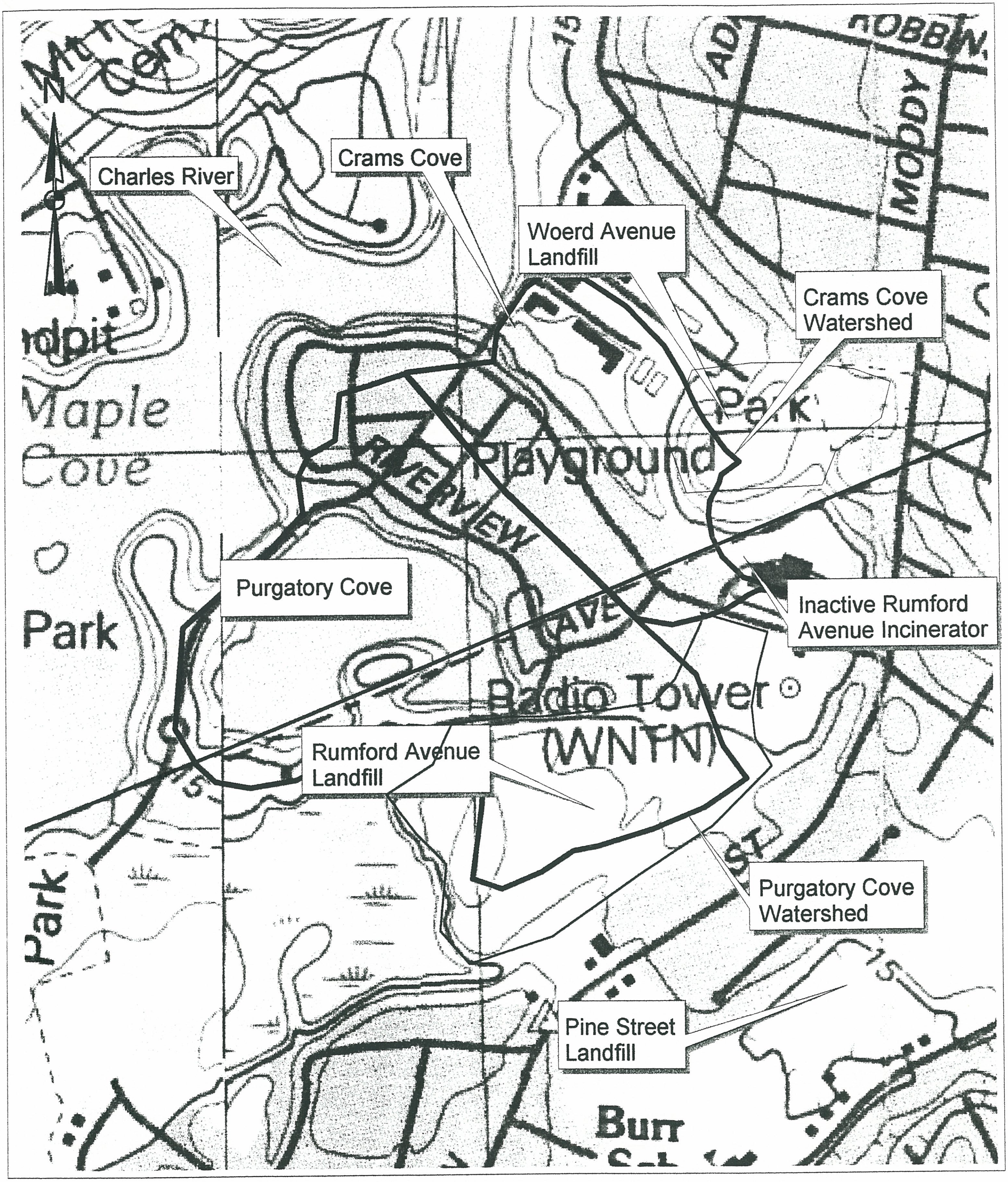

Figure 3. Watersheds - Purgatory & Crams Coves

Last Revision Date: July 21, 1999
MassGIS, USGS Topo

Using MassGIS land use datalayers, land uses identified within Purgatory Coves' watershed include portions of the now capped landfill, light and heavy industry, urban open areas, high density residential areas and forest. The watershed to Crams Cove contains residential areas on the southern boundary, portions of the Woerd Avenue landfill, and light industrial uses on the northern edge.

The former Rumford Avenue incinerator is located on the edge of the surface watershed. The former Parker Hannifin site abuts Crams Cove and was listed with the Massachusetts Department of Environmental Protection as a Massachusetts Contingency Plan (MCP) site in 1990. The MCP listing indicates that contamination or a spill has occurred at the site, action may be ongoing or completed to cleanup the site. Further information regarding its cleanup status is available through the Massachusetts Department of Environmental Protection office in Wilmington.

The Rumford Avenue landfill has been capped and is currently being used for composting activities. At the request of the Charles River Watershed Association the capping included creation of a wet pond to capture nutrient runoff from the composting activities. No further remediation action has been proposed. The landfill capping has significantly reduced the landfill leachate into the groundwater and thus into the cove. It is difficult to assess the condition of current leachate into the cove, but it is probable that there is some ongoing contamination into the groundwater, although the capping has occurred undoubtedly reduced this source of pollution.

Surrounding the coves are various types of land uses, including residential and light industrial. Impervious surface area coverage is high and a stormwater drainage system is presumed to exist. A shoreline survey of the coves for stormwater outfall pipes and research into the stormwater drainage systems in Newton and Waltham would shed light on whether or not stormwater was draining directly into the Coves.

IV. HYDROLOGIC ANALYSIS

H&W conducted a preliminary hydrologic analysis to estimate a water budget and residence times for water in the coves. This type of analysis is necessary to before reviewing alternatives for restoration. Some previously suggested alternatives for restoration or improvement of water quality in the coves include increasing the size of the culverts to the Charles River or connecting the two coves via an underground pipe or canal. It was thought that either of these alternatives might improve water quality by increasing flushing and circulation.

Cove Bathymetry and Volume

Field measurements of bathymetry were done by H&W to provide information on basin morphometry and to accurately assess each cove's volume. The bathymetric readings were taken along transects in each cove on April 2, 1999, using a Model 448 Depth Sounder Recorder. Both coves exhibited a flat morphometry, with little variation in depth along the transects. The total volume of water in Purgatory Cove was 17,985,750 gallons on April 2, 1999, with an average water depth of 4 feet. The volume in Crams Cove was 3,396,765 gallons, with the average depth in Crams Cove being 5 feet. The bathymetry measurements taken in Purgatory Cove are similar to those made in 1975 (Metcalf & Eddy, 1975).

Water Flow Exchange Rates

Horsley & Witten also measured water flow at the opening to the coves on April 2, 1999, to estimate the volume of inflow from the Charles River. A pygmy current meter was placed in each of the culverts. Results indicate no measurable flow into or out of the coves through the culverts to the Charles River. Surface water movement was observable, but was likely due to wind. Wind driven advection maybe an important component in such shallow water.

A second attempt to measure water flow using water elevations was done on May 6, 1999. Water elevations taken on May 6, 1999, in the coves and in the Charles River indicate a very slight hydraulic gradient in the direction of Purgatory Cove. These measurements were preceded by a week of rain; approximately 0.75 inches fell from May 1 to May 6. Discharge measurements at a stream gaging station downstream of the coves indicates a substantial drop in flow just prior to the field examination (USGS, Waltham stream gage). Further investigation revealed that diversions upstream into Mother Brook from the Charles upstream of the coves had occurred on May 3, 1999. The very small difference in water elevations measured was within the analytical error of the method. The flow rate measured at this time, therefore, appeared to be insignificant. Despite this it is expected that water flow will be from the river into the coves during and after large rain events, which would increase the level of the river in the Lakes District.

Watershed Area

Based on USGS topographic maps, the approximate watershed to Crams Cove is 21 acres while the cove's water surface area is approximately 2 acres. Purgatory Cove's watershed area is approximately 40 acres, with a water surface area of approximately 13.8 acres (Figure 3). The Metcalf and Eddy (1975) report estimated that 18 acres of land contribute stormwater runoff directly to the Purgatory Cove. It was assumed that the difference from the estimate in the 1975 report and our total acreage for the surface watershed is due to a correction for paved areas, which are serviced through stormwater drainage systems and do not contribute water to the coves. Further information regarding stormwater discharge and drainage system would be needed to verify this assumption. The 1975 report does not offer any information as to the drainage system. The MDC 1975 reported 18 acres of overland water runoff was used in our analysis. For Crams Cove, we estimated one acre of overland runoff within the watershed, assuming a similar paved area as the adjacent Purgatory Cove watershed.

Water Budget

It was assumed that groundwater recharge occurred only within the estimated non-paved areas. Annual recharge rates for the area range from 16 to 20 inches per year for stratified drift; we used 16 inches per year. We assumed groundwater recharge was contributing to the coves, despite the thick peat on the bottom of Purgatory Cove. Annual precipitation is 42 inches while evaporation is 20 inches per year (pers. comm. Mindy Roberts, Charles River Watershed Association; NOAA, 1982). Groundwater contours were assumed to follow surface topography and the area of groundwater contribution is the same as the surface watersheds in area.

The water levels within both coves are likely in equilibrium with the Charles River. Neither cove existed prior to the placement of the Moody Street Dam in Waltham. The level of the Charles River regulates the amount of water that is within the coves, and the level of the river in this area is controlled by the Moody Street dam. No quantitative historical data exists for water levels in the Lakes District. The water level does occasionally go below the level of the Moody Street dam or just trickle over it during the summer dry season (pers. comm. Nick Winter, MDC Moody Street Dam operator). When this occurs, water may reverse its flow from the coves to the River, when the coves' surface water levels are less than groundwater elevations, the groundwater will move into the coves. The groundwater is most likely a relatively small component of the total water budget of either cove. Several other studies (Metcalf & Eddy, 1975, Camp Dresser & McKee, 1995) found the bottom of the coves to be overlain with a thick layer (15-54-foot) of organic peat and silt which is typically not very permeable. The Horsley & Witten study did not examine low flow conditions when water quality conditions are most likely to worsen.

A major change in the water budget that has occurred since the 1975 report by Metcalf & Eddy is the rerouting of stormwater from the 60-inch stormdrain. This input represented 68% of the coves annual water input (Metcalf & Eddy, 1975, Table 3). This represents a significant decrease in the amount of freshwater flow entering into Purgatory Cove . The Metcalf & Eddy report (1975) concluded that Purgatory Cove only exchanges its water completely once or twice during the summer, when water quality is most impaired.

To evaluate water exchange, H&W prepared an estimate of residence times based on the hydrologic analysis done. This was done to provide an estimate of the order of magnitude of time that the water stays within these coves. Realistically, there would be storm events which would elevate the river elevation and provide water to the coves, which would decrease these residence times. Under the stated conditions, Purgatory Cove would flush completely every 309 days and Crams Cove would flush every 630 days (Tables 5 and 6). These long residence times probably exacerbate the water quality in the coves. Our field work and evaluation of they hydrology is similar with the conclusions drawn in the 1975 Metcalf & Eddy report--that circulation is restricted and that water entering into the coves during the summer months is minimal. The main difference from the previous investigations is the elimination of 68% of freshwater flow into Purgatory Cove, thus reducing the total volume of freshwater entering the Purgatory Cove and increasing the residence time.

V. RESTORATION AND REMEDIATION ACTIVITIES

H&W reviewed both ongoing and potential restoration and remediation activities. These are described below.

Ongoing Remediation Activities

Described below are some ongoing remediation that will alleviate or stem groundwater contamination. These include:

Table 5. Hydrologic Analysis – Purgatory Cove (no flow condition)

	Assumptions	gallons/year
Inputs		
Precipitation	42 in/yr	15,737,531
Groundwater Recharge	16 in/yr	7,819,891
Overland Runoff	18 acres	5,131,804
Inflow Charles River		Not measurable
	Total Input	28,689,226
Outputs		
Evaporation	20 in/yr	7,494,062
Outflow Charles		Not measurable
	Total Output	7,494,062
	Input-Output	21,195,164
	Annual Flushing	1.18 times/year
	Residence Time	309 days

Table 6. Hydrologic Analysis – Crams Cove (no flow condition)

	Assumptions	gallons/year
Inputs		
Precipitation	42 in/yr	2,383,438
Groundwater Recharge	16 in/yr	434,438
Overland Runoff	1 acre	285,100
Inflow Charles River	Not measurable	Not measurable
	Total Input	3,102,976
Outputs		
Evaporation	20 in/yr	1,134,970
Outflow Charles	Not measurable	Not measurable
	Total Output	1,134,970
	Input-Output	1,968,006
	Annual Flushing	0.58 times/year
	Residence Time	630 days

1) Woerd Avenue Landfill Site Assessment and Capping. The Woerd Avenue landfill located in Waltham is located in the watershed to Crams Cove. The City of Waltham is in the process of completing a Comprehensive Site Assessment of the landfill. This report will be available soon and future uses and remediation of this site will then be evaluated (personal communication, Town Planner, City of Waltham).

2) Rumford Avenue Incinerator Site and Storm Drainage Ditch. The Rumford Avenue Incinerator Site is being capped as part of a Phase III Massachusetts Contingency Plan. The proposal is to cap the contaminated sediments with pavement and allow development. A drainage ditch that lies between the Rumford Avenue Incinerator Site and the Woerd Avenue landfill has been sampled as part of the cleanup of the site. The ditch appears to drain into a storm drain; however there is no reported record of where the drain discharges (Camp Dresser & McKee, 1998). The contamination is assumed to be from either or both the Woerd Avenue landfill and/or the former incinerator site. Sediment and water quality samples at the ditch contained both metals and several polyaromatic hydrocarbons. The report compares the surface water concentrations to the ambient water quality criteria. Cadmium, copper, lead, mercury, silver and zinc concentrations were above acutely polluted concentrations. Other metals were present in chronic pollution concentrations. Sediments were compared to maximum background concentrations found in the Charles River in the Lakes District. The report states that there is a potential risk from sediment to benthic organisms as a result of acute and chronic exposure to cadmium and phenanthrene. No action has been recommended as of yet for remediation of the drainage ditch. Capping of the sediments of both the incinerator site and the landfill in the future will decrease the amount of contamination entering the ditch via groundwater and surface water runoff.

3) Mitigating Nutrient Overloading. Eutrophication is a widespread problem in the Charles River, due to a multitude of point and nonpoint sources

upstream. In addition, the excessive growth of the water chestnuts and other macrophytes may be contributing somewhat to the process. In 1997, Brandeis University conducted a season long survey of the water chestnut growth and an unsuccessful pilot project examining the effectiveness of a biological control to stem the growth of the invasive plant. Excessive growth has been somewhat remediated through the harvesting of the water chestnut by the Metropolitan District Commission. The harvesting process has a twofold purpose, to stem the growth of the invasive species and reduce organic decomposition as the plants die off, thus removing nutrients from the system.

The regional problem of nutrient overloading in the Charles River is currently being addressed by multiple agencies. It is desirable to work with other agencies, such as the Charles River Watershed Association, to reduce point and nonpoint source pollution entering the Charles River

4) Improving Public Access. Currently the Metropolitan District Commission (MDC) is attempting to improve public access to the Charles River through development of a river corridor greenway through Watertown, Newton, Waltham and Weston. This greenway would connect the lower Charles River Basin with the Lakes District (Master Plan, Charles River). As of 1997, the MDC was hoping to develop remaining sections through other funding sources such as the Intermodal Surface Transportation Efficiency Act (ISTEA), commercial abuttors, and local communities.

5) Reducing Nonpoint Source Pollution. The Charles River Watershed Association (CRWA) is working to reduce nutrient loading to the River by overseeing stormwater drainage issues in many towns in the Charles River watershed, as well as other point and nonpoint pollution sources. The Foundation may wish to identify the stormwater outfalls in the area of the coves and implement best management stormwater practices.

Possible Further Restoration and Remediation Activities

A number of restoration or remediation activities that could be considered are described below.

1) Wetland creation in Crams Cove. Compatible clean soils could be placed in the cove and seeded to become a wetland. Allowing this area to become a wetland would stabilize contaminated soils and increase the visual appeal of the cove. An analysis of whether such a wetland would be hydrologically sustained would be required prior to design. Other costs would include the cost of finding clean soils, purchasing wetland plants and/or seeds, labor etc. The permitting process to undertake this could be considerable, and would require state, local and federal permits. Any proposed work would require support from the Metropolitan District Commission since both Purgatory and Crams Coves are within their jurisdiction.

2) Dredging of contaminated sediments from Crams Cove. One possible restoration activity is to dredge sediments from Crams Cove. Disposal of these contaminated sediments at the Woerd Avenue landfill prior to its capping may be a potential disposal option. The feasibility of such action would need to be determined.

3) Dredging Purgatory Cove. The 1975 Metcalf & Eddy report evaluated dredging the bottom sediments of Purgatory Cove to allow the use of the cove for motorboats. The report offered two recommendations, 1) limit the recreational use of the coves to small nonmotorized craft, to eliminate the need for dredging, 2) dredge the cove to a depth in which bottom sediments are not effected by motorboat operation. The report surmised that dredging of the cove to a depth of 6 feet (the depth at which motorboat operation would be allowed) would be a costly undertaking, mainly due to disposal of contaminated sediments. It is estimated that 51,000 cubic yards of sediment would need to be removed to accomplish this goal.

4) Remove debris from Crams Cove. During this study, many tires and trash bags were encountered within Crams Cove, particularly at the western end, adjacent to the Woerd Avenue landfill. Removal of debris within the cove would improve visual appeal and attract attention to the cove.

5) Pollution prevention measures. To prevent further trash disposal in Crams Cove, options that might be considered include posting signs, directing police attention to the area, increasing citizens' awareness, and installing fencing where the trash may be entering.

6) Bank restabilization. Around the coves themselves, bank restablization projects along the roads that overpass the culverts and along private property that abuts the coves could be examined to decrease sediment and nutrient loading however, significant water quality improvements from these measures is unlikely.

Capping of a landfill is a common, cost-effective way to prohibit further leaching of contaminants into the ground. Below are additional ways of containing and preventing groundwater contamination from entering surface water bodies.

1) Passive treatment wall. To prevent additional groundwater migration, a containment structure or wall may be placed as a barrier between the surface water and the landfill. Passive treatment allow the passage of groundwater while prohibiting the passage of contaminants.

2) Slurry wall. These walls are often used in conjunction with capping of landfills or other hazardous waste sites to prohibit further contamination of downstream sites. These subsurface barriers consist of a vertically excavated trench that is filled with slurry. This kind of technology is used where the waste mass is too large or where soluble, mobile constituents pose an imminent threat to a drinking water supply. Most slurry walls are

constructed of a soil, bentonite, and water mixture. Slurry walls are typically placed less than 50 feet in depth and are generally 2 to 4 feet thick. Slurry walls may degrade over time depending upon the specific contaminant types. (Groundwater hydrology, engineering costs and construction costs most likely make underground wall construction cost prohibitive, and it would alleviate only one of the potential threats to Purgatory and/or Crams Coves (i.e. contaminated groundwater).

The MDC 1975 report, reviewed by H&W, provides the most detailed feasibility analysis for increasing dissolved oxygen in Purgatory Cove. A biological oxygen demand budget was performed to analyze the sizing of equipment that would be required for aeration—the report estimated that 600 pound per day would be needed to satisfy Purgatory Coves' oxygen demand and maintain the Class B standard of 5 mg/L.

The following are brief summaries of the alternatives proposed in 1975 for increasing the dissolved oxygen levels in the coves to meet the Class B standard of 5 mg/L in Purgatory Cove (Metcalf & Eddy, 1975):

- Pumping river water into Purgatory Cove from the Charles River. The Charles River water was found to have significantly more dissolved oxygen. The report estimated that a pump station with the capacity for 34 mgd (million gallons per day) would be required, along with a pump station, a force main and submerged outlets to release the overflow. This alternative would, when running at full pump capacity and a 6-foot water depth, turn over the water in the cove 1.5 times per day.

- Pumping of Charles River water into the cove, but lessening the total volume needed by saturating the pumped water with oxygen before pumping into the cove.

- Siphoning cove water out of the cove to a downstream location past the Moody Street Dam.

- Mechanical surface aeration of the cove with 4-10 horsepower floating units. The use of the mechanical surface aerators would require the depth of the cove to be increased to at least 6 feet. (Final recommended action in the report).

- Diffused aeration of the cove, similar in theory to the previous alternative.

- Constructing a channel from the Charles River upstream of the cove outlet to the southwestern end of the cove and allowing natural flow through the cove. Surface water elevations indicated there was no significant difference in elevation and thus flow would not occur. The report concluded that a channel linking the two bodies of water would be stagnant with little or no flow. Because of similar findings of surface water elevations in this current report connecting the Purgatory and Crams Coves via a channel is not recommended. Similarly, connecting the river to the Purgatory Cove via a channel is not recommended.

- Creating a water diversion into the channel by constructing a levee into the river was also considered and dismissed due to a lack of current velocity in this area of the Charles. A low head lift pump was also considered to create flow in a channel into the cove. The report concluded that this would only serve to increase circulation and dissolved oxygen in the western half of the cove.

- Increasing the culvert size. Anecdotal evidence revealed that residents felt that the cove began to deteriorate when the 80-foot wide inlet-outlet was replaced with a 15-foot diameter culvert. The report concluded that although this undoubtedly did reduce circulation, that enlarging the inlet-outlet to 80 feet would not be sufficient to improve water quality in the cove. It was suggested that lowering the flashboards at the Moody street dam periodically may flush out the cove.

In conclusion, the Metcalf & Eddy report recommended that in order to increase dissolved oxygen concentrations in the cove to the state standard, mechanical aeration is the best and most cost effective choice. In 1975, the capital cost for mechanical surface aeration of Purgatory Cove was estimated to be approximately $95,000. Aeration of the water in the coves may have the secondary benefit of oxidizing the metals in sediments. In general, metals in the oxidized phase are less biologically available than metals in the reduced phase. Increasing water circulation and water exchange rates has the benefits of increasing habitat for fish and wildlife.

Increasing circulation or creating an additional connection between the coves and the Charles River would potentially introduce more oxygen, but may also introduce more nutrients. From a hydrologic perspective, increasing the size of the culverts to the Charles River will do little to alleviate the circulation problem, because the head differential or water elevations will not be changed. The amount of differential required between the surfaces of the two water bodies would need to be far greater than presently measured to decrease the residence time enough to improve water quality. An engineered solution, as suggested in the 1975 report, would most likely be required to create a difference that would improve water quality. In conclusion, hydrologic findings from this study are similar to those found in the feasibility analysis conducted in 1975 regarding increasing circulation and increasing dissolved oxygen in coves.

VI. RECOMMENDATIONS

In order to pursue restoration and remediation of the coves, H&W recommends that the following measures also be considered:

- Monitoring of the cove's water quality is critical to undertake should the Foundation decide to pursue restoration. Monitoring water quality parameters will allow for evaluation of the restoration activities and act as a measure for success or failure. Monitoring can be done by properly trained citizens groups.

- Maintenance. Maintenance includes active work to review the condition of the coves on a regular basis and undertake routine activities to clean up, improve or maintain a given condition. Crams and Purgatory Coves could be adopted by the Foundation and cleaned and maintained in accordance with the MDC guidelines.

- Educational Outreach Programs. Educational programs and public outreach is critical for creating interest in improving the coves' conditions. The MDC is always looking for groups who would like to become involved in education; for example, involving school age children in the greenways and educating the many people who do not even know they exist. A public outreach campaign could be undertaken by the Foundation to advertise these new areas. Education tools such as placards placed along the greenways may be another way for the Foundation to become involved in publicizing the river.

- Creation of a Purgatory and Crams Cove Task Force. Several potential restoration activities have been provided in this report, some new and some from previous investigations. Because of the multitude of issues surrounding these coves it is recommended that a Purgatory and Crams Coves Task Force be formed to formulate a vision for these coves. Many ongoing activities, such as the Woerd Avenue Landfill Capping, the reuse of the Rumford Avenue incinerator Site, the extension of the Charles River Greenway, have potential impacts and offer opportunities for collaboration and coordination in dealing with the complex issues within the coves. It is recommended that, as a general principal, major stakeholders should be included in this Task

Force. For example, major stakeholders could include, local municipal officials, water managers, resource managers, citizens groups, researchers, and special interest groups. Agencies and groups that have been and are currently involved in this area include, the Charles River Watershed Association, the Cities of Waltham and Newton, the Metropolitan District Commission, the Island Neighborhood Foundation, the Massachusetts Department of Environmental Management and Brandeis University.

The following matrix (Table 7) may assist the Foundation and others in examining the desired goals/uses and the potential solutions that would be needed to reach that particular goal. The matrix describes some possible desirable restoration goals and activities that may further these goals; a yes indicates that the activity will address the restoration goal, possibly indicates more information would be required, and a blank indicates that no information was available on the applicability of the activity to the goal.

Table 7. Restoration Matrix

	Restoration Activity					
Restoration Goals	**Wetland Creation**	**Aeration**	**Dredge Sediments**	**Cap Sediments**	**Increase Circulatio n**	**Stormwater* Management**
Increased Oxygen		Yes	Possibly		Yes	
Reduced Nutrients	Yes	Possibly	Possibly	Possibly	Possibly	Yes
Increased Swimming		Yes	Yes	Yes	Yes	Yes
Increased Fishing & Fish Habitat	Possibly	Yes	Yes		Yes	Yes
Increased Boating			Yes			
Visual Enhancement	Yes	Possibly			Yes	Yes
Contain Cont. Sediment	Yes		Yes	Yes		Yes
Precipitate Metal Cont.		Yes			Yes	

*if stormwater is found to be a problem

Gaps in Data and Understanding

After reviewing the available information, H&W has identified some potential data gaps that the Foundation may need to fill depending on restoration goals.

- Quantify measurable input from Charles River during episodic events (storms, floods)
- Research stormwater drainage systems in the watersheds of these coves.
- Identify "hot spots" of contamination through mapping and analysis of existing data, potential gathering of new data.
- Identify any additional sources of pollution in the watersheds.
- Conduct sediment toxicity testing of "hot spots" in sediments for evaluation of sediment options.
- Further evaluation of nutrient pollution
- Clarifying sources of contamination and examining there relative inputs. Potential sources include the Charles River, groundwater, sediments in the cove, and stormwater runoff.

CONCLUSIONS

Purgatory and Crams Coves exhibit stagnant conditions, related to a very low rate of water exchange with the Charles River and historically decreasing freshwater inputs over time. A variety of sources of groundwater and surface water contamination occur in the area. Sediment and water quality is characterized as poor to moderately poor, relative to state standards, based on a review of the available data. A number of ongoing remediation activities are briefly reviewed. Selecting a future restoration approach depends heavily upon setting a definite goal for restoration.

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