

Fresh Kills Park, Phase 3A, Task 8.3
CONCEPTUAL ROADS REPORT

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Prepared for:

New York City Department of Parks and Recreation

Prepared by:

ARUP

155 Avenue of the Americas
New York NY 10013

Geosyntec Consultants

10015 Old Columbia Road, Suite A 200
Columbia, MD 21046

HDR/ Daniel Frankfurt

500 7th Avenue, 15th Fl.
New York, NY 10018

AKRF, Inc.

117 East 29th Street
New York, NY 10016

field operations

475 tenth avenue 10th floor
new york, new york 10018
t. 212 433 1450
f. 212 433 1451
www.fieldoperations.net



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EXECUTIVE SUMMARY

Introduction

The scope and schedule for this first conceptual phase of road design for Fresh Kills Park call for the development and screening of a range of alternatives based on the Draft Master Plan for Fresh Kills Park (Figure M-1). The range is to be narrowed to three (3) alternatives for inclusion in the Generic Environmental Impact Statement (GEIS) in September 2007. The schematic design phase that will follow, extending to the end of 2007, will develop, assess, and differentiate among the three GEIS alternatives to provide a basis for selecting a single preferred alternative to be carried into detailed design in early 2008.

Figure A-1, which was adapted from the vehicular network proposed in the Draft Master Plan, shows the complete primary road system comprising:

- Access improvements to the West Shore Expressway (Route 440) corridor,
- Introduction of the confluence loop to facilitate circulation within the Park, and
- Two loop connections to Richmond Avenue, at Richmond Hill Road and Forest Hill Road, that move around the landfill's east mound (Section 6/7).

The schematic design phase will ultimately focus on the entire park drive system. The concept phase focused on alternatives alignments at the east mound.

Alternative Alignments

The primary choices to be made in the conceptual design phase involve how to best move around or across east mound. The team considered a range of options in three corridors around the east mound, shown in the diagram at right. The three corridors include the western and eastern alternatives for linking the confluence loop with Richmond Hill Road, and a southern corridor for linking the loop with Forest Hill Road. In each corridor, three possible placements of the road were evaluated: (1) outside the perimeter of the landfill; (2) on the bed of the existing DSNY perimeter service road; and (3) on the landfill mound (referred to in the report as off-landfill, on-service road, and on-landfill respectively). The alignments resulting from these three placements are indicative of the overall range of potential placements within each corridor.

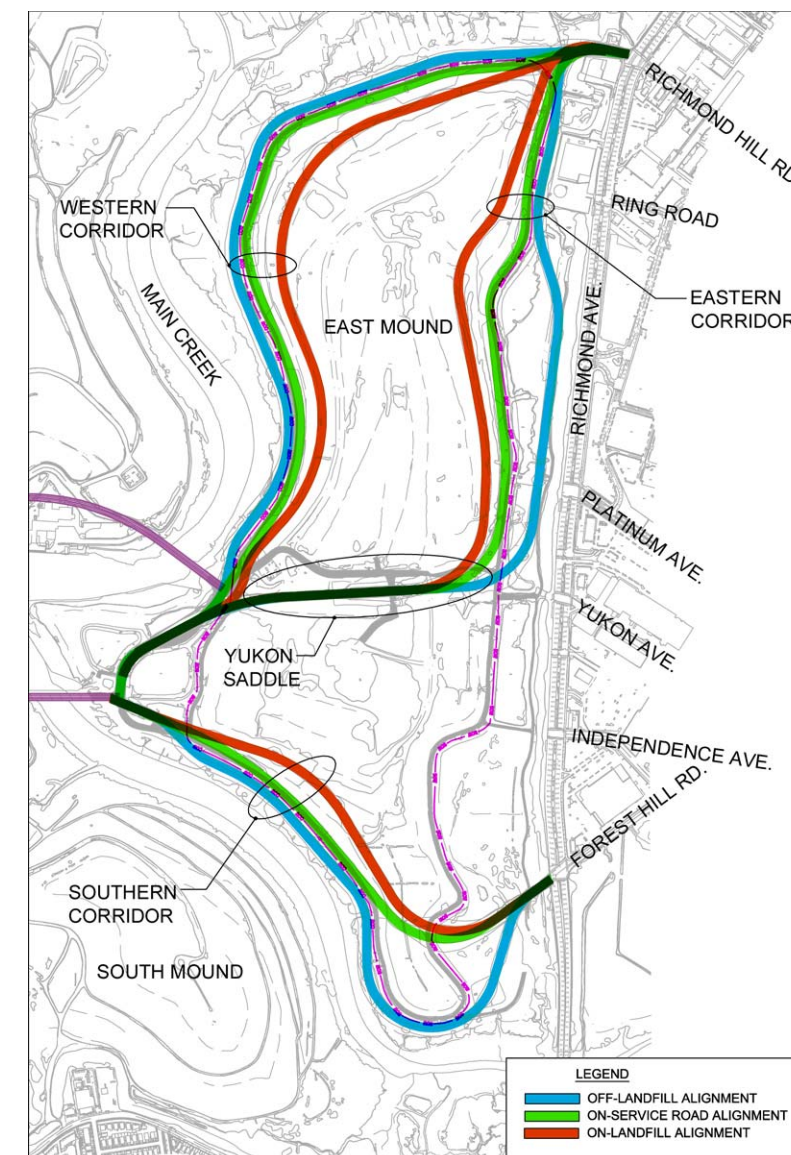
Representative cross sections were developed for two-lane and four-lane roadways to study the extent to which road width may affect the choice of corridor or alignment. A total of 18 alternative alignments (3 corridors x 3 positions x 2 widths) were considered.

Three sets of criteria were considered in the development and evaluation of the alternatives:

- Park design criteria aimed at integrating the roads into the vision of the park as a regional destination with concentrations of major amenities served by park roads, situated in a green, ecologically vibrant context that is largely non-motorized.
- Roadway design criteria in compliance with the AASTHO Policy on Geometric Design, as endorsed by NYSDOT and NYCDOT, based on design speeds of 45 mph for the West Shore Expressway

service roads and ramps, and 35 mph for the Park roads, supplemented by goals geared to design excellence, innovation and sustainability. The road criteria assume the roads will be designated park drives rather than city streets, as discussed in section 2.3.

- Landfill engineering and maintenance criteria, intended to ensure the integrity of all landfill systems, compatibility with DSNY's planned closure construction program, and ongoing access for monitoring and maintenance.
- Sustainability criteria, to ensure that the Park is environmentally, economically and socially sustainable. Sustainability principles will be incorporated into the roadside, pavement, materials, stormwater management and construction practices.



Three corridors around the east mound.

Alignment Screening Process Findings

The screening process resulted in important findings:

- All on-service road alignments result in embankments that would rise from 5 to 15 feet above the existing landfill perimeter service road and the leachate collection system it is intended to serve, interfering to unacceptable levels with landfill infrastructure and long-term operations.
- The off-landfill alignments in the western corridor along Main Creek, and in the southern corridor along Richmond Creek, would require extensive filling in tidal wetland and wetland buffer areas, have severe environmental consequences, and reduce Park appeal because road embankments would block waterfront access and views.
- The on-landfill alignments in the western and eastern corridors would traverse some of the thickest, most unconsolidated layers of waste shortly after they have been permanently capped, which would necessitate cap reconstruction and result in significant long-term differential settlement and road degradation due to the limited vertical reach of foundation improvement measures such as preloading.
- The on-landfill crossing at the Yukon saddle (a portion of the eastern corridor) which divides the north and south halves of east mound, rests on a thinner layer of waste, as well as some strong fill material such as slag, that has been consolidated by loaded trucks delivering garbage and cover soils on DSNY haul roads. This portion of the corridor has much greater strength to support a park drive. An added benefit is that the haul road alley through the saddle has also been kept generally clear of landfill infrastructure.
- The depth of waste in the southern half of east mound is shallower than the north, and it thins further as it approaches the southern boundary of the landfill along the southern corridor. It is anticipated that preloading would be effective in limiting long-term settlement and road degradation in the southern corridor to acceptable levels.
- The eastern corridor off-landfill alignment parallels an existing berm bordering Richmond Avenue and takes advantage of level ground occupied by an existing access road. While it intrudes into landfill drainage basins, there are many opportunities to create additional freshwater wetlands elsewhere.

Recommended East Mound Alignments

In synthesizing the screening findings, a clear preferred alignment for the roads around the east mound emerges. For the northern link from Richmond Hill Road to the confluence loop, the off-landfill path in the eastern corridor, combined with a crossing at the Yukon saddle, is the most feasible of the alignments reviewed. For the southern link connecting Forest Hill Road to the loop, the on-landfill placement stands out as the preferred alignment.

Part A of this report describes the evaluation criteria, the alternative alignments screened, and the design team's conclusions and recommendations. Part B provides additional insights into the technical and regulatory issues related to the on-landfill roadway, to help establish a degree of confidence that the challenges can be resolved, and to develop better understandings of particular issues and possible solutions.

Recommended Alternatives for the GEIS

In keeping with the GEIS scoping process, the recommended alignments at east mound that will be considered in the schematic phase will be a two-lane roadway, four-lane roadway and a hybrid. The confluence loop will be similarly evaluated as a two-lane and four-lane roadway. The other important element of the primary park road system, the West Shore Expressway improvements, will also be developed in further detail for evaluation in the GEIS.

In summary, the three alternatives recommended for inclusion in the GEIS are:

- The confluence loop and the Forest Hills and Richmond Hill connectors designed as four-lane roads, together with the West Shore Expressway ramp and service road improvements.
- The confluence loop and the Forest Hills and Richmond Hill connectors designed as two-lane roads, together with the West Shore Expressway ramp and service road improvements.
- A favorable combination of four-lane and two-lane loop and connector elements, together with the West Shore Expressway ramp and service road improvements.

The Department of Parks and Recreation and the design team seek comments on the findings and recommendations presented in this report.

1. INTRODUCTION

1.1 Background

The Fresh Kills Park project has advanced from the Master Planning phase into the conceptual design and environmental assessment phase—a step closer to realization.

The conceptual phase of roadway design began in May 2007, with the exploration of alternative approaches to integrating the primary road system as defined in the Draft Master Plan (Figure M-1), into the Park design in keeping with the transportation needs of the island, the constraints of landfill engineering and the protection of natural resources and other Park goals. .

The scope for this first phase of design called for the development of six (6) conceptual roadway alternatives that adhere to the Mater Plan, to be narrowed to three (3) during the concept design phase. The Generic Environmental Impact Statement (GEIS) scoping process calls for the assessment of three (3) alternatives: one four-lane alternative; one two-lane alternative, and one hybrid that would favorably combine elements of four-lane and two-lane elements.

Rather than settling on 6 alternatives to investigate, the road design team reviewed a more comprehensive range of alignment and width options—18 in all—in order to provide the widest possible base of information for decision makers' selection of the three alternatives to be further developed for inclusion in the DGIS. The three alignments selected will be advanced through schematic design in the fall of 2007, and further narrowed to a single preferred alternative by the end of 2007. A related decision, being addressed separately, is whether the roads within the Park are to be mapped, built and operated as park roads or city streets.

1.2 Report Format

The report is presented in two parts. Part A focuses on the primary objective of narrowing the range of alternatives to the three to be evaluated in more detail in the GEIS. Part B is dedicated to road/landfill interface considerations to help reviewers gain a deeper understanding of the unique constraints that influence road design at this site. The figures at the end of the report include plans, profiles, and cross sections of the alternatives under evaluation, as well as details that illustrate how certain specific landfill interface challenges discussed in Part B may be addressed.

1.3 Purpose

The purpose of this report is to summarize the road design team's inquiry to date and create a framework for selecting the three (3) preferred alternatives that will be carried into the schematic design phase and evaluated in the GEIS. To support this process, Part A of this report:

- describes the corridors through which the primary road system could be routed
- analyzes possible road positions within the corridors
- screens the alternatives for major flaws
- identifies the elements that appear to comprise the most promising alignments
- recommends the alternatives to be advanced in the GEIS and schematic design

To winnow the alternatives from the current group to the three (3) alternatives to be forwarded through the GEIS process, steps were taken to:

- Outline the service road and ramp configuration at the West Shore Expressway, as a component of any alternative acted upon.
- Confirm the general configuration of the confluence loop.
- Determine the preferred corridor for the northerly connection between the confluence loop and Richmond Avenue, whether to the east side or west side of east mound (also known as landfill section 6/7 and future East Park),
- Determine a suitable road placement in areas where landfill slope, landfill cut-off wall, infrastructure, or wetlands conflict with potential alignments.

Focusing on the issue of road placement, the three ways to categorize alternative positions within a particular corridor are identified as: (1) off-landfill; (2) on-service road; and (3) on-landfill. Together, these three positions are indicative of the range of potential placements for a particular connector, and were selected to reveal major flaws that would most directly influence the screening out of alternatives.

The report focuses more extensively on the four-lane roadway as the GEIS will carry that as the base build road alternative. It was also felt that the wider roadway alignment associated with the four- (4) lane alternative would more effectively reveal functional, regulatory and engineering opportunities and constraints. Nonetheless, while the decision on the four- vs. two-lane versions is not being made at this time, concept designs of the two- lane alternatives have been progressed and the cross sections included in this report to allow them be considered in assessing the various alternatives.

To substantiate that the recommended alignments will be viable, Part B of this report:

- Offers possible solutions to some challenging areas along key segments of the recommended alignments.
- Identifies further studies for confirming viability and addressing primary issues, to help structure the next phase of design.

The schematic phase that follows the selection of the three GEIS alternatives will develop, assess, and differentiate among them during the fall of 2007 and provide a basis for determining a single preferred alternative to be carried into detailed design in early 2008. The schematic level engineering will address significant roadway network and landfill interface issues and identify solutions. In the subsequent preliminary design phase, those solutions will be honed and integrated into a comprehensive set of measures for the entire primary road system that will be detailed in the final design to follow.

A secondary purpose of this document is to serve as briefing material for a preliminary value engineering session in October and the basis of an order of magnitude cost estimate to be submitted later in September. A second package on the conceptual design of the bridges will accompany this document for OMB and its reviewers.

Part A

Defining the Park Road System and GEIS Alternatives

2. ROAD DESIGN PARAMETERS

A brief overview of the entire primary roadway system provides context for the choices to be made. This section identifies the primary road network components shown in the Draft Master Plan, presents the criteria guiding their conceptual road design, summarizes the related pending decision of whether the roads should be city streets or park roads, and outlines the criteria guiding the design.

2.1 Road Network

Figure A-1, adapted from Fresh Kills Park Draft Master Plan proposed vehicular circulation network, shows the complete primary road system, comprising:

- the West Shore Expressway (Route 440) corridor
- the confluence loop, and
- two connections to Richmond Avenue, at Richmond Hill Road and Forest Hill Road.

A view of the proposed connections along the West Shore Expressway (Route 440) corridor and the confluence loop is shown on Figures A-2 and A-3. The design calls for the extension of the Expressway service roads, linked by underpasses on both sides of Fresh Kills creek, to improve continuity and provide interconnectivity with the confluence loop and the Park road system. Discussions with NYSDOT have led to the inclusion of an additional exit ramp - entrance ramp combination in the northbound direction between Arden Avenue and the West Shore Expressway bridge over Fresh Kills creek. In the southbound direction, the design incorporates the relocation of the Arthur Kill Road exit ramp from south to the north of Arden Avenue, and the addition of a new entrance ramp south of Arden Avenue.

Figure A-2 also shows the proposed roadway system bordering north mound and south mound, forming a loop around Fresh Kills creek, referred to as the confluence loop. Its path is dictated by existing conditions at several critical locations – the two existing bridge crossings over Main Creek and Richmond Creek (that connect the North and South Mounds with the East mound), the narrow passages under the West Shore Expressway bridges on both sides of Fresh Kills creek, and by the boundaries of the North and South mounds – such that there remains little leeway in the placement of the loop road. The loop includes a new aesthetically distinctive “signature” bridge crossing over Fresh Kills creek to the west of the West Shore Expressway, to be completed in a later stage of the Park’s implementation. Both four (4) lane and two (2) lane configurations will be considered for the whole as well as parts of the Loop during the schematic design phase.

As presently configured, the loop intrudes slightly onto the southeast corner of north mound. This condition and its associated impacts will be investigated and discussed with DSNY and DEC during schematic design.

Whereas conditions in the western part of the park tend to constrain roadway choices, multiple candidate alignments are under consideration at east mound, as shown in Figure A-1 and shown at larger scale in Figures W-1, E-1 and S-1. Section 2.5 further describes these alignments and a screening assessment of them is presented in Section 3 of the report. The candidate alignments terminate at two intersections on Richmond Avenue: at Richmond Hill Road and Forest Hill Road, converting both intersections from three-way to four-way intersections. The configuration of all intersections will be determined in conjunction with traffic projections, which are under review with NYCDOT.

It is anticipated that the new roadways, if approved as part of a build alternative, would be constructed in stages. Landfill closure progress, funding, accessibility and a number of other factors will be considered in establishing an implementation schedule. At this time it is envisioned that the most essential and cost effective roadway connections will be constructed at the earliest opportunity and that highly desirable but more costly elements, such as the new iconic bridge crossing over Fresh Kills Creek, would be deferred to the latter stages of Park development.

2.2 Design Criteria

The design criteria are presented in three parts, as warranted by the site’s unique history, and its special future setting as a world-class park:

- Park design criteria
- Road design criteria
- Landfill design and maintenance criteria

2.2.1 Park Design Criteria for the Roads

The Fresh Kills site imposes unusual restrictions on road design, from the extensive landfill infrastructure that underlies more than half of the site to the wide expanses of wetland that line nearly all potential circulation corridors. In addressing the engineering difficulties, the design cannot lose sight of the ultimate goal—to create a world-class park.

Roads at Fresh Kills Park are to be designed to enhance the natural setting, and provide access to it, not diminish it. In the spirit of U.S. National Parks and Scenic Byways, Fresh Kills Park drives will be designed as an integral feature of the park experience – an attraction in and of themselves. Distinctive materials and a broad landscape corridor should differentiate park drives from standard city streets and cue motorists that they have entered the park. Sensitive siting within the topography and a graceful layout will enable drivers to appreciate the scenic views and the topographic variability. The road design and materials should also be as sustainable as possible and the latest technologies should be incorporated to use sustainable materials, manage stormwater, minimize ecological impact and provide a safe, durable road.

More specifically, to the extent possible, Fresh Kills roads should achieve the following:

- Enhance the motorist experience with curvilinear layouts, graceful ascents and descents, and smooth passage through the park.
- Incorporate grade separations along curves and soft “green” borders.
- Create a consistent, legible orienting system – in terms of geometries, widths, materials, edging, lighting, signage and markings – that identifies the road as a park feature.
- Use sustainable and durable materials.

The Fresh Kills Park circulation system is expected to create a new critical east-west traffic relief link between Richmond Avenue and the West Shore Expressway without dominating the park. Roads should

provide maximum connectivity through minimal infrastructure. Thoughtful siting within the topography, the establishment of a wide planted corridor, and distinctive paving materials should integrate the roads into the landscape, preserve the dramatic scale of the site, and ensure that the park is a calm refuge.

- Vehicular circulation within the park should be limited to key routes that serve the primary program areas and network connections. In support of sustainability goals, the circulation system should be planned to maintain movement of traffic and reduce potential for pollution from start-stop activity.
- The water's edge should remain free of road infrastructure in order to preserve the integrity of the wetland and to enable continuous pedestrian access to the creeks.
- Wherever possible, primary road linkages should include a 300' landscape corridor that blends the road into the larger natural setting, buffers drainage, and accommodates non-vehicular circulation.

Fresh Kills Park roads should offer the opportunity to enhance the ecological quality of the site. In order to fulfill this promise, however, an explicit choice must be made for an alignment that impacts existing wetlands as little as possible and incorporates sustainability principles as much as possible. The Fresh Kills Park circulation system should meet the following specific goals:

- Place roads above the 10' contour and outside of the wetland buffer as much as possible.
- Create an extensive system of healthy wetland systems that compensates for any impacts on existing wetland (which are to be minimized through thoughtful ecological design)
- Design a landscape corridor as a robust habitat and stormwater treatment system.
- Incorporate landscape corridors as road segments are constructed to compensate for any adverse habitat effects.

The design of the Fresh Kills Park drives must consider engineering constraints, but it must also embrace ecological, sustainability and aesthetic standards that are unprecedented in the New York City arterial system.

2.2.2 Road Design Criteria

As integral elements of the park, the design approach for the Park Drive system will incorporate the latest approaches to building sustainable roads and arterials, the latest approaches to developing scenic arterials and the latest approaches to minimizing impacts of road infrastructure on habitat corridors, while providing for the safety of park users and motorists.

Adherence to suitable geometric criteria is a key component of safe road design. Road criteria are presented below, adapted to the particular context in which the road will operate. Consequently, separate design criteria are included for the WSE Service Roads and Ramps, the proposed Park Roads, and affected Landfill Service Roads as follows.

- West Shore Expressway Service Roads and Ramps

Design Speed	45 mph
Lane Width – Service Roads	2@ 12'
Lane Width – Ramps	15'
Shoulder Width – Service Roads	4' left, 10' right
Shoulder Width – Ramps	3.5' left, 6.5' right
Grade	6.0% maximum, 0.5% minimum
Horizontal Curvature	711' minimum radius (e = 4%)
Superelevation	4% maximum
Stopping Sight Distance	360' minimum (horizontal and vertical)
Lateral Clearance	1'-6" minimum
Vertical Clearance	14'-6" minimum
Travel Lane Cross Slope	1.5% minimum, 2.0% maximum
Rollover	4% maximum between travel lanes 8% maximum at edge of travel way
Control of Access	Maintain full access control to the West Shore Expressway

- Park Roads

Design Speed	35 mph
Lane Width	11' for four-lane one lane operation 12' minimum for two-lane operation, provide for bypass
Shoulder Width	2' minimum, 6' desirable
Median width	0' minimum, 4' desirable
Bridge Roadway Width	Same as approach roadway on new bridges Reduced median and shoulders on existing bridges
Grade	8.0% maximum, 0.5% minimum
Horizontal Curvature	371' minimum radius (e = 4%)
Superelevation	4% maximum
Stopping Sight Distance	250' minimum (horizontal and vertical)
Lateral Clearance	1'-6" minimum
Vertical Clearance	14'-6" minimum
Travel Lane Cross Slope	1.5% minimum, 2.0% maximum
Rollover	4% maximum between travel lanes 8% maximum at edge of travel way

The posted speed limit is usually set at 5mph below the design speed for values in this range.

- Landfill Service Road Relocations

Portions of active landfill access roads that would need to be modified, relocated, or reconstructed to accommodate Park roads will be designed to be continuous and consistent with the adjoining undisturbed segments and to be satisfactory to DSNY and DEC.

2.2.3 Landfill Design and Maintenance Criteria for Roads

The New York State Subpart 360 Landfill Regulations do not contain either design criteria or a required methodology for design of roadways over landfills. Nonetheless, it is the design team's understanding that the design of the Fresh Kills Park roads must satisfy a minimum performance standard stated as follows:

- The design of the roadway cannot compromise the function or integrity of the existing landfill environmental control systems and the design must maintain protection of the environment consistent with the level of protection provided under permit and permit equivalent requirements for the landfill.

Consequently, the standard for this road design goes beyond sound engineering analysis and preparation of construction documents. The design must also include a plan for the systematic monitoring of construction activities, to document that construction is consistent with the design, and a plan for post-construction monitoring to document the long-term integrity of the landfill environmental control systems that may be influenced by the presence of the roadway. The design will likely also include field demonstrations and measurements to verify design concepts and material parameters during the design process.

The design team understands that to meet the performance standard described, the road design must meet requirements defined by the NYSDEC:

- The cut-off wall and leachate collection trench, which contain and collect leachate (i.e., water that has come in contact with waste), must not be damaged and their function must not be compromised. The continuity of the geosynthetic landfill cap and natural soil liner, which control infiltration of rainwater into the waste mass from above and exfiltration of leachate through the base of the landfill, must be maintained to prevent generation of additional leachate or release of leachate into the creeks, basins or groundwater.
- The stability of the landfill and roadway embankments must be evaluated and assured.
- Landfill infrastructure affected by deep dynamic compaction (DDC), if this method were employed, would need to be rebuilt, because repeated use of a heavy weight to compact foundation material may damage landfill infrastructure.
- The dynamic loading of the landfill foundation by vehicles traveling on the roadway must be considered in the design analyses.
- A specific plan for monitoring the landfill environmental control features following construction must be prepared.

The Fresh Kills Park road design is to be supported by documentation presented in a manner similar to that required for a landfill permit application (i.e., New York State Regulations, Subpart 360-2.3). The design package is anticipated to include five primary documents.

- A Geotechnical Investigation Report
- A Report of Field Demonstration of Pile and Natural Soil Liner Compatibility
- An Engineering Design Report.

- A Construction Quality Assurance Plan
- An Operations and Maintenance Plan

These are further described in Part B, section 4.2.

2.3 Park Roads or City Streets

Building on the principles espoused in the *High Performance Infrastructure Guidelines* report authored by the New York City Department of Design and Construction (DDC), these roads have the opportunity to demonstrate integrated sustainable planning through the use of durable materials and innovative technology and design that exert minimal impact on the surrounding environment, allow for animal crossings, and support the flow and expansion of wetlands. Drainage, construction materials, medians, shoulders, landscaping, maintenance procedures, relationship to pedestrians and bicycles, lighting, all are potentially unique conditions that will need to be carefully evaluated during the design process.

As with every construction project in New York City, a process for review and approval must be established that the involved parties can comfortably participate in. In the case of the primary road system for Fresh Kills Park, two paths of approach are under consideration.

- Map and develop the primary road system as New York City streets within the park
- Map and develop the road system as part of the park

In a process paralleling the development and evaluation of alignment alternatives covered in this report, DPR has requested that the design team undertake an assessment of the two approaches. The team's assessment was summarized in a separate report that is currently under review. That report concludes that the park drive designation will result in lower capital costs, a much shorter review and approval schedule, and better compatibility with landfill constraints and park objectives. The full application of city street requirements - such as the inclusion of sewers and water lines on stable supports - will constitute **fatal flaws** due to their incompatibility with landfill closure and maintenance requirements.

The design team believes that designation of Fresh Kills roadways as park roads rather than city streets will best suit all three sets of criteria—park, road design and landfill criteria—as well as the logistics of park construction. Nonetheless, the team recognizes that the decision is yet to be made. The premise of this report is that the design will be advanced as a Park road. Should that turn out to not be the case, several aspects of the report would have to be reconsidered.

2.4 Application of Road Design Criteria

This section highlights how key criteria and geometric and safety standards, and related design considerations have been applied to specific roadway elements in developing the plans, profiles, and indicative sections used to define and evaluate the conceptual alternatives considered in the report.

2.4.1 West Shore Expressway Service Roads and Ramps

The service roads and ramps are being designed in accordance with the AASHTO Policy on Geometric Design of Highways and Streets 2004 version (Green Book) with regard to spacing, and the 2006 edition of NYSDOT's Highway Design Manual (HDM) with regard to geometry.

The typical service road section consists of a 4-foot left shoulder, two 12-foot lanes, and a 10-foot right shoulder. The typical ramp section includes a 3.5-foot left shoulder, a 15-foot lane, and a 6.5-foot right shoulder. Both typical sections are shown on Figure TS-1. The ramp terminals will be the tapered type shown in Figures 6M through 6N of the NYSDOT 2006 Highway Design Manual.

The proposed configuration is shown on Figures A-2 and A-3. The plans show that the new ramp arrangement can be accommodated in both the northbound and southbound directions, but with little room to spare.

2.4.2 Park Roads

The typical Park Road sections adopted for conceptual design purposes are shown in Figure TS-1. The four-lane section includes 11-foot lanes, a flush 4-foot textured median, and 6-foot shoulders which may also be textured. The two-lane section includes 12-foot lanes, a 4-foot textured median, and 6-foot shoulders. The combination of median, lane and shoulder widths on the two-lane road allows for bypassing of a stalled vehicle, such that a single stopped vehicle does not block an entire direction of travel. The shoulders will also contribute to improved sight distance along the inside of curved roadway segments and help keep the roadside clear of hazards. Along the confluence loop, the median and shoulders may need to be narrowed to fit in the constrained width of the existing haul bridges and the passages beneath the West Shore Expressway.

The pavement structure has not been designed, but is expected to be composed of flexible asphaltic surface, binder and base layers over a granular subbase course, founded on a suitably prepared subgrade. Special attention will be needed to prepare the subgrade, especially on the landfill, as discussed in section 4 of the report, and to integrate sustainability principles.

A typical side slope of 1 on 3 (33%) is consistently assumed for the embankments for the purpose of comparing the large group of alternatives in this conceptual design phase. The slope is traversable and reduces the need for the barrier protection imposed by steeper slopes and limits the footprint and associated disturbance to wetlands and the landfill that would otherwise result from flatter slopes. The slope is generally consistent with that on the sides of the landfill mounds. In advancing the short list of three alternatives in schematic design, the side slopes will be adjusted to better fit roadside conditions: steepened where guiderail protection will be needed, such as in close proximity to water bodies; flattened to 1 on 4 or shallower where space for errant vehicle recovery (the ability for vehicles to safely regain control) can be included. Best

Management Practices will be included to prevent landfill and other site runoff from encroaching on the roadway pavement.

These parameters were adapted as needed to the park roads in the confluence loop. They were applied consistently to all corridors and all alignments at the east mound to provide a consistent basis for comparing the various options considered there. Section 2.5 describes these options.

2.4.3 Landfill Access Roads

Certain landfill access roads are to remain active until the landfill closure process is complete, and others are to provide access for landfill maintenance and repair activities for many years to come. Consequently, a fundamental goal of park roadway design is to avoid interference with landfill access roads. Where interference cannot be avoided, the landfill road is to be relocated such as to retain its functionality. If relocation is not a sensible solution and it becomes necessary for the park road to also serve as the means of access to landfill infrastructure, pullouts and staging areas will be incorporated in the design to minimize conflicts between travel and maintenance activities.

To the extent that relocation or reconstruction of active existing landfill access roads becomes necessary, they will be designed to be continuous with the adjoining segments and include such specific modifications as may be necessary to meet their functional requirements.

2.5 East Mound Corridors and Alignment Alternatives

The circulation plan included in the Master Plan (Figure M1) calls for linking the Park roadway system with two intersections at the north and south ends of east mound: at Richmond Avenue/Richmond Hill Road, and Richmond Avenue/Forest Hill Road. Further, it shows two alternative, mutually exclusive routes for the connection to Richmond Hill Road, herein referred to as the western and eastern corridors. The more promising of these two corridors will be combined with the southern corridor to complete the park drive system.

Representative alignments for the three potential roadway positions within the corridor: (1) off-landfill, (2) on-service road, and (3) on-landfill, were developed in both plan and profile for each corridor.

- The off-landfill alignments were placed outside of the cutoff wall that marks the landfill's boundary at an elevation of two or more feet above the 100-year flood level. The profile varies minimally, to allow for longitudinal drainage.
- The on-service road alignments were developed with the intention of taking advantage of the level space already occupied by the 20 to 22-foot wide landfill access road that runs the entire perimeter just inside the leachate trench and cutoff wall, while protecting and maintaining access to critical infrastructure – the leachate trench, leachate, collection infrastructure and cutoff wall.
- The on-service road placement is that the proposed road will have to accommodate both the full complement of park road functions and service road functions. As such it will need to incorporate additional safety and traffic management measures, such as pull outs, staging areas, and access control at all critical landfill infrastructure features.
- Given that the leachate collection chambers (spaced approximately 600 feet apart along the entire east mound perimeter) require regular, and possibly extended-term access for maintenance or repair,

placing such facilities anywhere within the travel way is deemed unacceptable from both functional and safety perspectives. Consequently, the proposed new road is placed entirely inside the leachate system, with its outer edge generally coincident with the outside edge of the existing landfill service road (except where park road curvature requirements prevailed). The consequence of the inside placement is that in order to avoid cutting into the side of the mound and removing large volumes of waste, as well as completed portions of the closure cap, all the way up to its top, the proposed road must be raised to where the width between the outer edge of the existing service road and receding mound slope becomes sufficient to accommodate the proposed two-lane and four-lane roadways along each of the corridors.

- In similar fashion, the on-landfill alignments were developed with the intention of avoiding cutting into the mound side slope, as well as minimizing the placement of extensive additional fill over the mound that would chase the slope all the way to the bottom and extend onto the existing service road, compromising or negating its use. Consequently, for each corridor, the placement moved up the mound's side slope in sequential steps, and the plan and profile adjusted accordingly, until a shelf was found that would generally accommodate the proposed roadway without chasing the slope to the top or bottom of the landfill.

2.5.1 Western Corridor

The western corridor extends along the northern and western sides of east mound, and alongside Main Creek and its associated wetland zone, for essentially its entire length between Richmond Avenue and the confluence loop.

Alignments, profiles and cross sections were developed and explored for the off-landfill, on-service road, and on-landfill positions for both the four-lane and the two-lane versions. It is important to note that the landfill mound is presently in the process of being capped, with final closure to be completed ahead of roadway construction, for the length abutted by the western corridor.

Representative alignments for the three alternative roadway positions within the corridor: (1) off-landfill, (2) on-service road, and (3) on-landfill, are shown on Figure W-1, their respective profiles on Figures WP1, 2 and 3 and the resulting cross sections on Figures W4-1, 2, 3 and 4 for the four-lane version, and Figures W2-1, 2, 3 and 4 for the two-lane.

The key consequences associated with each of these alignments are discussed in section 3.

2.5.2 Eastern Corridor

The eastern corridor which runs along the east side of east mound, consists of two distinct segments: parallel to Richmond Avenue between Richmond Hill Avenue and Yukon Avenue; and over and across the east mound in the saddle that separates the north and southern halves of the mound in line with Yukon Avenue.

The parallel segment is sandwiched between the mound and commercial property, a Department of Sanitation Garage, and two stormwater drainage basins that separate the mound from Richmond Avenue. Richmond Avenue is screened by a planted berm up to 30 feet in height for much of this length. A gravel auxiliary service road runs between the berm and the drainage basins.

The significant difference in the first segment is that it veers well away from the landfill. Factors favoring the Yukon saddle as a potential mound crossing include: its current and past use as a landfill access road, its mixed underlying fill material, the relative absence of gas infrastructure and the schedule for final closure in 2009 and 2010, which could allow for the design of the landfill cap and roadway to be coordinated in a functionally integrated and cost effective manner.

Representative alignments for the three alternative roadway positions in the north-south segment paralleling Richmond Avenue are shown on Figure E-1, their profiles on Figures EP-1, 2, 3 and 4 and the resulting cross sections on Figures E4-1, 2, 3 and 4 and Figures E2-1, 2, 3 and 4. All three alternatives share the same conceptual alignment through the Yukon saddle. If advanced, the best placement of which would be determined in cooperation with DSNY and DEC and in light of the considerations outlined in section 4 of this report.

2.5.3 Southern Corridor

The southern corridor connects Forest Hill Road with the confluence loop. Between Forest Hill Road and east mound, the corridor crosses wetlands targeted in the Draft Master Plan for major improvement, because current vegetation in the area is of poor quality. Consequently, the roadway across this segment is conceived as resting on a viaduct rather than on an embankment, since the short length (relative to what would be required in the eastern or western corridors) does not appear to be prohibitively costly.

The rest of the corridor extends along the southern slope of east mound, alongside Richmond Creek and its associated wetland zone. There are significant differences between the south end of the east mound as compared to its north end that offer improved on-mound potential are: a considerably lower waste depth and the later closure schedule, which could make it possible to advance road design and landfill closure construction in coordinated, integrated fashion.

Representative alignments for the three alternative roadway positions are shown on Figure S-1, their profiles on Figures SP-1 and 2 and the resulting cross sections on Figures S4-1, 2, 3 and 4 and Figures S2-1, 2, 3 and 4.

3. SCREENING OF EAST MOUND CORRIDORS AND ALIGNMENTS

The many possibilities at the east mound need to be winnowed to the combination that best meets the project goals. This section evaluates each of the three corridors and each of roadway placements within each corridor by identifying fatal or overriding flaws and impacts of inferior alternatives.

The section concludes with the identification of the least flawed elements that combine to form the most promising solution at the east mound. The team provides a recommendation of the alternatives to be advanced in the GEIS.

3.1 Western Corridor



The plan view of the alternative alignments within the western corridor is provided on Figure W-1, wherein off-landfill, on-service road, and on-landfill are shown, respectively, in blue, green, and red. The corresponding profiles are shown on Figures WP-1 through 3.

However, the outcomes and implications associated with the alternatives in the corridor are most readily discerned from composite cross sections that show the three roadway positions side by side, based on the typical Park Road sections included on Figure TS-1. The resulting side by side comparisons at four representative points along the corridor are included as Figures W4-1, 2, 3 and 4 for the four-lane version, and W2-1, 2, 3 and 4 for the two-lane, wherein the colors correspond to those on the plan.

An assessment of the major impacts and overriding flaws related to each of the three roadway placements follows.

3.1.1 Off-Landfill Placement

The off-landfill alignment avoids significant interaction with the landfill infrastructure. In developing the off-landfill option the roadway was placed outside and as near the landfill cutoff wall as possible, at an elevation above the 100-year flood level, with conceptual allowances for drainage. In the western corridor, an off-landfill road would have to be constructed on a berm in the wetlands or on structure as there is only a narrow strip of land between the landfill perimeter and open water. Much of this section of Main Creek includes tidal wetlands that have been mapped by the DEC, that have been mapped as part of the National Wetlands Inventory, requiring a US Army Corps of Engineers (ACOE) permit, and designated as significant coastal fish and wildlife habitat by the New York State Department of State (NYS DOS). All three agencies would be involved in the review of any impacts to these designated areas, DEC and ACOE in a permitting capacity. This alignment would be costly to construct in either the 2-lane or 4-lane scenarios and would impact upon significant wetland areas.

- It is estimated that the alignment could impact up to 14 acres of land area below the 10-foot contour line as currently surveyed. This would include activities such as filling and grading in both tidal wetlands and tidal wetland adjacent areas, interrupting mapped high marsh, intertidal marsh and some formerly connected wetlands linked hydrologically and ecologically with the William T. Davis Wildlife Refuge to the north.
- A portion of the roadway will be constructed within existing tidal wetland areas, which would require review by NYS DOS and permitting by DEC and ACOE. Assuming about half of this area (7 acres) is tidal wetlands, mitigation under the Tidal Wetlands Act and SEQR may require 24 to 32 acres of new or substantially improved tidal wetlands. Under the two-lane alignment this potential impact reduces to 11 acres of impacted tidal wetlands adjacent area (estimated at 5 to 6 acres of tidal wetlands), or an estimated mitigation area of 15-24 acres. In either case, from a natural resource perspective, an alignment with less impact on tidal wetlands would be much preferred.
- If there are other viable alternatives with substantial wetland impacts, it may be difficult or impossible to get permits for this alignment.
- Soft soils within the tidal wetland area would likely not provide an adequate foundation for embankment roadway construction without engineering modifications such as overexcavation and replacement, and sheet pile bulkheads.
- A significant volume of fill would need to be imported to achieve a finished roadway elevation above the 100-year flood elevation; alternatively, construction of the roadway on a pile-supported viaduct would be costly.
- Placing the roadway on water's edge restricts park visitors' contact with Main Creek. Without massive wetland filling in addition to that for the roadway, a waterside pedestrian/bike path would not be possible in this scenario.
- No creek-side space would be available for a landscape buffer that would provide habitat, filter road runoff to reduce wetland impacts and reduce the visual prominence and noise of the road.

The impacts associated with the two-lane alternative only differ from those of the four-lane alternative in degree. The roadway would be about two-thirds and the base of the embankment approximately three-fourths as wide, resulting in the same list of issues.

3.1.2 On-Service Road Placement

This position on the slope was intended to alleviate a significant portion of the shoreline and wetland impacts as well as major impacts on the landfill cover systems, and to provide a strong, compacted road base that minimizes the depth of waste under the road. In developing this option, the outside edge of the proposed roadway was designed to generally coincide with the outside edge of the service road, to avoid placing the leachate system chambers, manholes, vents, and their frequently used access covers within the pavement area. Given that the existing perimeter service road is about 20 feet wide, and typically fitted between sloping sides, both the four-lane and two-lane versions which are approximately 60 and 40 feet wide, extend well outside the existing paved footprint and its plateau. The greater width is obtained by raising the new road surface to where its inside edge meets the side of the landfill without cutting into the landfill cover, which would necessitate reshaping extensive portions of the mound slope.

The consequence of raising the roadway profile is that this placement would still intrude into the environmentally sensitive creek shore and would cause disruption to landfill infrastructure and long-term operations as follows:

- To avoid cutting into the capped landfill, up to 10 feet of fill would need to be placed above the existing service road surface to achieve a finished roadway that integrates properly with the existing slope, with the necessary stormwater management provisions.
- Existing leachate collection and pumping station enclosures would need to be vertically extended to meet the final grade elevations and traffic bearing covers installed.
- The top of the leachate cutoff wall would need to be protected and hardened to alleviate the load from the overlying roadway fill.
- Should repairs to the leachate trench and cutoff wall become necessary, the high overlying embankment will severely hamper access. In addition, such interventions would result in disruption and potential closure of the Park Road.
- The existing service road would be eliminated and landfill maintenance vehicles and activities would have to share the road with park users and commuters. Even with the addition of auxiliary pavement, the slower movements and stoppages of maintenance vehicles are likely to cause friction with faster vehicles and safety concerns. A separated maintenance road is not feasible as it would not be able to access the critical infrastructure lying in the area of the cut-off wall.
- Auxiliary accommodations for parking and filling of over-the-road tanker trucks used to collect landfill gas condensate would need to be incorporated into the design. Special precautions for protecting landfill maintenance personnel from roadway traffic would need to be implemented during periodic maintenance of the leachate pumps or electrical systems.
- Placing the roadway on the service road still results in intrusion into the wetland buffer and diminishes the opportunity for and appeal of a waterside pedestrian/bike path.
- Minimal space would be available for the landscape buffer and filtration of road runoff.

Again, the impacts associated with the two-lane alternative differ from those of the four-lane alternative in degree. The narrower roadway would not require as high an embankment over the existing service road, reaching a height of 6 feet above the leachate trench, nor extend as far laterally. Nonetheless, the list of issues would read much the same.

3.1.3 On-Landfill Placement

In this alignment, the road is placed on the mound slope at a point where the road embankment does not impinge on critical perimeter landfill infrastructure features. Since the slope of the roadway embankment and that of the east mound are similar at approximately 33%, development of useful alignment, profile and cross sections required the testing of several side slope locations. The placement depicted was chosen because it rests on a shelf that is wide enough not to cause the new roadway embankment to chase the downhill side with fill onto the service road, nor to cut into the uphill side up to the next plateau. These constraints were considered important because this part of the landfill will already have met final closure requirements by the time of road construction.

While this placement avoids impacts on the Main Creek shore, the service road, and the leachate collection/cutoff wall system, it places the road far up on the slope, with projected elevations near elevation 90, high on the waste slope, with the following effects on the waste and other landfill systems:

- Placement of the roadway at this elevation may reduce the short-term slope stability factor of safety below the generally recommended value of 1.5. The calculated slope stability factor of safety at the final cover condition ranges from 1.54 to 1.76 along the northwestern portion of east mound (URS, "2003 Updated Slope Stability Monitoring System Report").
- Waste deposits could be expected to settle several feet due to mechanical compression and decomposition into the future. Measurements of vertical settlement up to 8 inches were recorded on mound 6/7 between October 2002 and October 2003 (URS, "2003 Updated Slope Stability Monitoring System Report"). This would significantly impact the overall maintenance requirements of the road and require additional up front capital cost to mitigate impacts.
- Foundation improvement techniques would be necessary to stabilize this waste prior to road construction. Even with preventive measures, more variability in settlement following foundation improvement could be expected due to the inability to reach and treat lower strata.
- The stabilization treatments will likely require a significant amount of energy or resources (i.e. more compaction effort, greater surcharge thickness, deeper drilling for stone columns) in attempting to better improve the long-term performance of material lower in the profile.
- Areas of the east mound adjacent to the western corridor are scheduled for closure in 2007 and 2008, ahead of roadway construction. To insure the integrity and performance of the landfill cover system, areas already capped would need to be deconstructed prior to foundation improvement and reconstructed as a part of roadway construction.
- The deconstruction and re-construction of the cover system would require that an area as wide as the roadway grading, plus an additional 25 feet on each side of the grading limits, be cleared of cover soils and the geomembrane cut at a location approximately 5-10 feet inside of the area that has been uncovered to apply roadway foundation improvements and modify the gas system. The geomembrane's cut edge will need to be cleaned and protected during roadway foundation improvement and base grading.

- The roadway position on the landfill would conflict with landfill gas wells, header and lateral collection lines. Modifications to the gas system features along the western slope of east mound would be necessary to accommodate roadway construction.
- After settlement or compression of the waste, soil backfill and regrading will be needed to restore surface integrity. In reconstructing the cover, the gas vent layer (under membrane composite) will be replaced by overlapping the new composite with the existing material, the new membrane must be placed and, welded, tested, certified, and accepted by the DEC. Similarly, the drainage layer geotextile or composite (above the membrane) will be replaced by overlapping with the existing material and the barrier soils (roadway subbase material) placed. Reconstruction of the geomembrane cover welds will likely be made using extrusion welds, which are more difficult to construct and test for continuity than fusion welds typically made along the edges of new geomembrane panels.

The impacts associated with the two-lane alternative differ from those of the four-lane alternative in degree. The narrower roadway would not require as wide a swath of the cover to be removed. However, the difficulties presented by long-term and differential settlement, and the complications associated with deconstructing and reconstructing the completed cover would be the same.

3.1.4 Western Corridor Conclusion

All three alignments prove to be problematic and undesirable in comparison to eastern corridor alternatives (see section 3.2).

The on-landfill alignment pushes the road well up the mound, interfering with views from the north mound and William T. Davis Wildlife Refuge, a condition that runs counter to the Park goal of leaving this northern section pristine and natural.

The 9 to 14 foot rise of the on-road scenario above the existing perimeter features significantly impacts upon landfill infrastructure and would compromise DSNY landfill maintenance and operations. The on-service road scenario proves to be the least desirable alignment in all three corridors as it consistently conflicts with critical landfill infrastructure and seriously compromises maintenance and operation requirements.

The on-landfill alignment rises to approximately elevation 90, traversing some of the thickest, most unconsolidated layers of waste that are presently being capped. This will result in significant initial and long-term settlement that will not adequately respond to preloading and other foundation improvement measures. Initial construction and the large initial settlement will require cap removal and reconstruction. Differential settlement will continue in the longer term, resulting in undesirable levels of degradation for both the road and the landfill, requiring excessive intervention.

In conclusion, the western corridor does not present favorable opportunities for accommodating a new road.

3.2 Eastern Corridor



The plan view of the alternative alignments within the eastern corridor is provided on Figure E-1, with the off-landfill, on-service road, and on-landfill shown again in blue, green, and red, respectively. As can be seen on Figure E-1, the variations apply to the northern portion of the corridor, as all three alignments converge onto the same line across the Yukon saddle. The corresponding profiles are shown on Figures EP-1 through 4.

The composite cross sections that provide comparative insights at four representative locations are shown on Figures E4-1, 2, 3 and 4 for the four-lane version, and E2-1, 2, 3 and 4 for the two-lane version. Evaluation of the potential issues related to each of the three roadway locations north of Yukon Avenue follow.

3.2.1 Off-Landfill Placement (North of Yukon)

The alignment turns south from Richmond Hill Road and traverses the embankment supporting the drug store and DSNY Garage, then crosses a large drainage basin to run adjacent to the berm, on the footprint of the auxiliary service road, running through the man-made drainage basins across to the side of the Richmond Ave berm and then the east mound at the Yukon saddle. This location takes advantage of the existing auxiliary road's footprint, thereby reducing intrusion into the basins, provides for better road geometry at the Yukon turn, and has fewer conflicts with landfill infrastructure. This alignment will likely compromise portions of the existing basins which are not mapped as tidal or fresh water wetlands by the DEC, but are mapped as part of the National Wetlands Inventory and will require review and permitting by the Army Corps of Engineers (ACOE). Additionally, since the entire site lies within the coastal management

zone, it will be review by the NYS Department of State. It is important to note however that there is no designation of significant coastal fish and wildlife habitat on the drainage basins in this area to the east of the east mound. The major impacts associated with this alignment follow.

- The estimated impacted area of the basins is 7 acres for the four-lane alignment and 6 acres for the two-lane alignment. The impacted area includes the DSNY constructed drainage basins lying to the east of the east mound. The roadway will intrude into the drainage basins east of the east mound, portions of which are mapped as freshwater wetlands in the National Wetland Inventory (US Fish and Wildlife Service). While listed as wetlands by the US Fish and Wildlife Service, none of the basins are mapped tidal or freshwater wetlands by the NYS DEC.
- This alignment would require filling of portions of the landfill stormwater management basin B-1, which could impact on natural resources and reduce the storage capacity of basin. However, the capacity of Basin B-1 would exceed the post-development storage requirements despite losing some storage volume. Drainage culverts discharging stormwater runoff from off-site areas along Richmond Avenue into the wetland area would need to be directed into new culverts.
- The roadway partially covers the landfill gas interceptor trench near Richmond Avenue. The trench, a generally shallow gravel trench approximately 3-ft wide, would need to be reconstructed as part of the roadway construction.
- The roadway will cross the landfill perimeter service road and climb the mound slope, creating embankments of up to 30 feet within stormwater basin B-1 and up to 25 feet at the base of the landfill. These will be analyzed and designed to support the added load and assure stability for the mound, the road, and the supporting soil. Embankment foundation improvements such as excavation and replacement, flattened embankment slopes, or mechanically reinforced slopes will be considered as necessary.
- Maintaining the perimeter service road calls for a separated grade crossing that will require the introduction of a bridge approximately 40 to 50 feet in length within or near the edge of the landfill cover system, where the primary road crosses the cut-off wall to rise up the east mound. One of the case studies in section 4 of the report begins to address the grade-separated crossing at Yukon by presenting three options for the placement of a bridge.
- The constrained space between the mound and drug store at the first turn Richmond Hill Road requires that the curve radius be reduced to 250 feet, commensurate with 30mph rather than the 35mph design speed. Considering that the turn leads to or from a stop condition at the intersection with Richmond Avenue, this is not deemed a significant problem.

The impacts associated with the two-lane alternative would differ from those of the four-lane alternative in degree. The smaller footprint would provide a significant advantage in its run along the berm. While the base of the roadway embankment would be approximately 80% as wide as the four-lane at the basin crossings, along the berm the narrower two-lane width would spill 50% less distance beyond the service road footprint and into the basins.

3.2.2 On-Service Road Placement (North of Yukon)

As with the western corridor, the outside edge of the proposed roadway is generally laid out to coincide with the outside edge of the existing perimeter service road, with similar consequences. This portion of the landfill is presently undergoing final closure. Here too the service road is much narrower than the proposed

roadway, causing the park road to be lifted in order to achieve the necessary width without cutting into the landfill cap. The height of embankment rises more than 15 feet above the existing road and the abutting landfill infrastructure facilities. This placement would produce all of the consequences outlined for the western alignment service road placement.

It is important to note that the DSNY service road would be compromised and that any separate bikeway established in this area would have to be established outboard of the road, necessitating either an at-grade crossings or additional bridges to reconnect with the interior of the Park.

The impacts associated with the two-lane alternative differ from those of the four-lane alternative in degree. The narrower roadway would rise approximately 10 feet, and not extend as far laterally. Nonetheless, the list of issues would read much the same as noted in the discussion of on-service road placement in the western corridor.

3.2.3 On-Landfill Placement (North of Yukon)

The road is placed on the mound slope at a point where the road embankment does not impinge on critical perimeter landfill infrastructure features. As in the western corridor studies, several positions on the slope were tested to find an adequate shelf for the road.

While this placement avoids impacts on the basins, wetlands, the service road, and the leachate collection/cutoff wall system, it places the road as high as elevation 90, with consequences comparable to those described for the on-landfill placement for the western corridor.

The narrower width of the two-lane version mitigates the degree, but not the nature or complexity of the issues associated with a high, on-mound position in a closed area of the landfill.

3.2.4 On-Landfill Placement (Yukon Saddle)

As noted, the Yukon saddle is not scheduled for final closure operations until 2009 and 2010. It provides a substantial band of space relatively free of landfill infrastructure that can accommodate a road; and may be underlain by stronger and better compacted material. This path merges with any of the three options north of Yukon to complete the eastern corridor.

This portion of the eastern corridor provides engineering challenges, particularly at the climb onto the slope and the crossing of the confluence of major drainage lines near its western connection to the Loop. Studies to address conditions along the Yukon saddle have been initiated and will be progressed in schematic design. To this point, no evidence has been uncovered that renders this portion of the corridor infeasible.

Refer to section 4, in Part B for further discussion of initial studies of alternative engineering approaches to resolving issues along the Yukon Saddle.

3.2.5 Eastern Corridor Conclusion

The eastern corridor has significantly more potential than the western corridor. The primary challenge in the eastern corridor is rising to and crossing the Yukon saddle to connect to the confluence loop. However, as noted, the condition of the landfill in the area of the saddle is more conducive to accepting the road construction than many other parts of the landfill.

The on-service road and on-landfill alternatives are more problematic than the off-landfill alignment. The former rises up to 17 feet above the existing service road, interfering unacceptably with landfill operations and maintenance functions. The on-landfill alignment rises to elevation 90, inviting all of the problems associated with construction on very deep, capped waste.

The off-landfill alignment will require mitigation of the impacts that will result from building into and alongside the DSNY-constructed drainage basins adjacent to the east mound and the need to build a large structure or embankment to connect the road across the Yukon saddle. However, as discussed in Part B, these issues are not insurmountable. The off-landfill alignment allows for continued landfill maintenance operations and makes the service road available for use as a bikeway system.

The off-landfill alignment is the preferred alternative in the east corridor and the recommended route for the connection to Richmond Hill Avenue.

3.3 Southern Corridor



The plan view of the alternative alignments within the eastern corridor is provided on Figure S-1 and the corresponding profiles are shown on Figures SP-1 and 2.

Three composite cross sections that provide comparative insights into the three conceptual roadway placements are shown on Figures S4-1, 2 and 3, and S2-1, 2 and 3 for the four- and two-lane versions, respectively.

Evaluation of the potential issues related to each of the three roadway locations are provided below.

3.3.1 Off-Landfill Placement

The position of the road relative to the landfill and Richmond Creek is similar to that of the western corridor relative to Main Creek. This placement would produce all of the consequences outlined for the western alignment off-landfill road placement for both the four-lane and two-lane versions. The initial link between Forest Hill Road and the southern toe of the landfill sits well above the DEC mapped wetlands associated with Richmond Creek and outside the NYS DOS designated significant coastal fish and wildlife habitat. The road does traverse across areas that listed in the national Wetlands Inventory, requiring ACOE review and permitting. Similar to the Western Corridor, the off-landfill placement impacts upon DEC mapped wetlands, significant coastal fish and wildlife habitat designated areas and wetlands mapped as part of the National Wetlands Inventory, necessitating review by DEC, NYS DOS and ACOE and permitting from DEC and ACOE.

- The estimated area of tidal wetlands affected is 9 acres for the four-lane alignment and 7 acres for the two-lane alignment. The tidal wetlands along Main Creek are linked hydrologically and ecologically with the LaTourette Park to the east.
- The proposed viaduct would traverse an area of wetlands that are designated in the national Wetlands inventory (US Fish and Wildlife Service) but this area between the Richmond Ave berm and the landfill is not mapped as tidal or fresh water wetlands by the DEC.
- A more definitive inventory of wetland locations will be undertaken as part of the Fresh Kills Park EIS, which could identify that a portion of this area as wetlands as they are connected to the larger estuary system of Richmond Creek. If identified, a mitigation plan will be required for any wetlands that are encumbered by the proposed roadway alignment.

3.3.2 On-Service Road Placement

In the southern corridor, the required height of embankment would place up to 13 feet of fill on top of the existing service road for a length of 30 to 40 feet. This placement would produce all the consequences outlined for the western alignment service road placement for both roadway widths, including compromising DSNY service and operations and necessitating the construction of a bikeway outboard of the road below the 10' contour line.

3.3.3 On-Landfill Placement

As with the other on-landfill placements, this alignment is placed on a shelf on the mound slope at a point where the road embankment does not chase the slope with additional embankment, nor cut extensively into the uphill side of the mound, nor impinge on the most critical perimeter infrastructure elements. The foundation will be on waste in an area of the landfill that may not have final closure completed by the time of road site preparation. Consequently, it may be possible to consider localized cutting where impacts can be mitigated and efficiency gained. This placement reduces impacts on the Richmond Creek shore, the service road, and the leachate collection/cutoff wall system, but will have some effects on landfill systems.

The conceptual design results in a roadway elevation ranging from 35 to 45 with an estimated 40 to 55 feet of waste beneath. Under these circumstances, the potential roadway design and landfill infrastructure issues are as follows:

- Stability of the waste slope along this alignment is expected to be controlled by waste properties because relatively weak recent clay and silt deposits are generally thin or not present along this corridor. Preliminary stability analyses of this roadway position on the landfill suggest that the factor of safety against sliding is greater than 1.5.
- Settlement of the waste is expected to be on the order of a few feet. Foundation improvements such as pre-loading could be used to reduce settlement prior to roadway construction. (Results achieved on other landfill roads are outlined in Appendix A.)
- Along the southern alignment, it may be possible to advance the construction of the road and closure in integrated fashion.

3.3.4 Southern Corridor Conclusions

As with the western and eastern alignments, the on-service road alignment compromises unacceptably landfill infrastructure and DSNY's ability to maintain that infrastructure.

The off-landfill alignment compromises the Main Creek wetland area, cutting off waterfront access or forcing the construction of the bike/pedestrian system in wetland areas.

The analysis of the southern corridor shows that an on-landfill solution is preferable because the impacts on the mound are not as severe as with the eastern and western alignment, and can be kept within acceptable levels due to the much lower waste depths involved, as can be seen on Figure TX-1.

The on-landfill alternative is the recommended alignment for the southern corridor connection to Forest Hill Road.

3.4 Recommended East Mound Roadway Alignments

Feasibility assessments for three alignments in each of three separate corridors were undertaken in order to develop a recommendation on a preferred routing at east mound. The recommendation is to connect the Richmond Hill corridor along the off-landfill eastern corridor and to connect the Forest Hill road alignment via the on-landfill southern corridor as shown in Figure A-4.

This recommendation is based upon a comparison of the issues faced with each of the candidate roadway corridors and the specific placement of the roadways within each corridor. The analysis uncovered a number of key differences relating to design, function, accessibility, maintenance, permitting, and landfill infrastructure interaction.

- The off-landfill placements of the western and southern corridors create highly undesirable environmental intrusions into the tidal wetlands in Main Creek and Richmond Creek along the east mound and in the tidal wetland adjacent areas. They block access to the Creeks, in direct conflict with some of the Park's primary objectives. Any grade-separated paths would have to be inboard of the road. If alternative alignments are considered feasible by permitting authorities, it may be difficult to obtain permits for the off-landfill placements.
- There are no DEC mapped wetlands designated in the eastern corridor or the entire eastern side of the east mound. The area is not considered as part of the significant coastal fish and wildlife habitat. However, portions of this area show up on the National Wetlands Inventory. Given that an Army Corps of Engineers permit will be needed regardless of which corridor is chosen, the fact that this area does not register as mapped DEC wetlands limits the permitting process to a single environmental review agency and supports the team's assessment that these wetlands are unconnected with the larger creek system. It will be relatively easy to compensate for losses in the freshwater systems by creating new freshwater habitat in the many landfill basins that are currently dry and rip rap lined.
- All on-service road placements, intended to minimize the impact on the landfill and on the abutting environment, result in prohibitive impacts to both. In fact, they interfere with and degrade the basic maintenance functions required of the service roads.
- On-landfill placements in the northern half of the mound would place the road on very deep waste with a relatively weak foundation layer, resulting in the largest settlements (several feet), and intrusion into completed areas of the landfill cap, necessitating its removal and reconstruction, with attendant risks, and the reconstruction of extensive portions of the gas system. The eastern corridor shows potential because the crossing at the Yukon saddle would pass over thin, uncapped, better supported landfill and offers a path relatively clear of landfill infrastructure. Similarly, on-landfill placement at the south end of the east mound has fewer drawbacks because it is considerably shallower than at the north end and may not be capped at the time that road site preparation would begin, allowing treatments to be more readily applied.

These points are key to determining the preferred alignments at east mound. As discussed in section 3.1.4, 3.2.5 and 3.3.4, they result in the following **recommendations**:

- **Adoption of the eastern off-landfill and Yukon saddle alignment for the connection to Richmond Hill Road.**
- **Adoptions of the southern on-landfill alignment for the connection to Forest Hill Road.**

The alignments are shown at a larger scale on Figures P-1 through P-5. Section 4 in Part B of the report considers in greater detail some of the key issues that need to be addressed in advancing this, or a comparable combination into the schematic design phase.

3.5 Recommended GEIS Alternatives

A primary purpose of this report is to define the overall park road system and assist in determining which road alternatives are to be advanced to more detailed study as build alternatives in the Generic Environmental Impact Statement (GEIS).

The recommended full park roadway system comprises:

- The West Shore Expressway corridor improvements
 - Continuous service roads on both sides of the Expressway, except for the Fresh Kills Creek crossing, connecting to the Park's confluence loop.
 - A new northbound exit ramp and a new northbound entrance ramp between Arden Avenue and Fresh Kills Creek, serving a new Park entrance approximately midway between them
 - A relocated southbound exit ramp between Muldoon Avenue and Arden Avenue, and a new southbound entrance ramp south of Arden Avenue serving the Muldoon Park entrance
- The new confluence loop, including two existing bridge crossings over Main and Richmond Creeks, two underpasses under the WSE, and a new iconic bridge across Fresh Kills Creek to the west of the WSE
- The connections to Richmond Avenue
 - A new connector road to Forest Hills Road that follows the on-landfill alignment along the south side of east mound,
 - A new connector road to Richmond Hill Road that follows the off-landfill alignment along the east side of east mound, including passage over the Yukon saddle

In keeping with the GEIS scoping process, three alternatives are recommended for further development in the schematic phase and more detailed evaluation in the GEIS.

The three recommended alternatives are:

- **The confluence loop and the Forest Hills and Richmond Hill connectors designed as four-lane roads, together with the West Shore Expressway corridor improvements.**
- **The confluence loop and the Forest Hills and Richmond Hill connectors designed as two-lane roads, together with the West Shore Expressway corridor improvements.**
- **A favorable combination four-lane and two-lane loop and connector elements, together with the West Shore Expressway corridor improvements.**

3.6 Next Steps

The next step in the development of the primary road system is to select the three alternatives to be carried through the GEIS process. The selection will be made by the Department of Parks and Recreation on the basis of internal reviews and the comments, inputs and suggestions offered by other involved agencies in response to this report. The Department of Parks and Recreation and the design team seek such input.

As part of the agency review, the New York City Office of Management and Budget (OMB) will evaluate the road system concept design and provide its input. The OMB will be applying its value engineering process to the conceptual designs the first week of October. Conceptual bridge drawings are being developed for review in the value engineering session.

Following selection, the three chosen alternatives would be advanced into schematic design and developed to a greater level of detail for the purpose of better understanding their fit, cost and impacts, and to highlight the substantive differences among them, to facilitate the selection of a single preferred alternative in January 2008.

Based on this report's recommendations, it is anticipated that some key areas of focus will be the impacts of a four- versus two-lane alternative at critical creek crossings, pinch points, and areas where the road rides over or may cut into the existing landfill cap. Additionally, bridge designs, intersection designs, associated parking areas, initial drainage designs, landscape buffer treatments and basic roadway materials will be considered, all predicated upon this initial determination of the three GEIS alternatives.

It is anticipated that the roadway system will be constructed in phases, with the phases to be determined based on which alternative is chosen, funding, and associated priorities.

Part B

Addressing Landfill Issues

4. ROADWAY / LANDFILL INTERFACE ISSUES

4.1 Overview of Technical Issues

Technical issues related to the recommended alignments are presented in this section. The overarching goal is to establish a level of confidence that the challenges of these alignments can be resolved in future phases of road design and engineering—that there are no fatal flaws that can be identified at this time. The technical issues are grouped into the following three categories: 1) waste foundations for roads on landfills, 2) construction of roadways over landfill infrastructure perimeter features, and 3) conflicts with other landfill system infrastructure features.

Following the overview, the criteria presented in section 2.2.3 are elaborated upon in 4.2, and two case studies are presented in section 4.3 and 4.4 which examine possible means of limiting landfill impacts and responding to key issues along two important segments of the east mound. Finally, in section 4.5, summaries of other projects are presented that provide background for the types of design and maintenance issues involved in constructing roads on landfills.

4.1.1 Waste Foundations for Roads on Landfills

There are two primary approaches for developing a suitable foundation for roadways over the landfill: 1) installation of piles to support a construction of an elevated roadway (viaduct) above the waste surface, or 2) cut/fill, consolidate and stabilize existing soils and waste to create a suitable subgrade for construction of the road at-grade. Possible design, construction, or maintenance issues associated with pile and at-grade foundations are presented in the following subsections.

4.1.1.1 Pile Foundations

- Piles could be used in either or both of the following situations: 1) along the entire roadway, to elevate the road above the waste; or 2) at locations where an abutment is needed to support an elevated section of road.
- Pile foundations can be constructed by drilling into the ground followed by subsequent installation/construction of the pile (e.g., drilled piers or piles), or by driving a preformed pile into the ground.
- A variety of driven and drilled pile types are available, each with certain advantages and disadvantages, some of the various pile types include: steel-H piles, circular steel piles, and pre-cast concrete piles.
- Pile foundations are typically more costly than embankment fill foundations.
- Pile driving would likely induce ground vibrations, and consequently may increase the pore-water pressures within the fine-grained subsurface soils. Any pile design must consider the need to prevent increased pore pressures from decreasing the resistance of the soil mass to movement and the potential for reducing the stability of the landfill slopes. The increased pore pressures would dissipate after a given time.
- The bearing capacity of a pile or group of piles is derived from either friction between the pile and the surrounding soils or by resistance at the tip when the pile is driven to the bedrock elevation.
- Inspection and maintenance of the seal between the landfill cap and the pile or pile system will be required to ensure that the cap is continuous and that gaps between the pile and cap

that form as the landfill settles around the pile, as previously experienced at other locations at the Fresh Kills Landfill site.

- The difficulties with inspection, maintenance, and repair will require that penetrations be minimized and carefully designed to allow effective inspection and maintenance to remediate gaps in the seal between pile and cap.

For many of the reasons cited, the use of piles is not contemplated at Fresh Kills, except for isolated instances where it can be demonstrated that they are essential, the landfill cover will be subject to minimal settlement, and special provisions for inspecting and maintaining the boot seal are included.

4.1.1.2 At-Grade Foundations

- At-grade foundations are typically less costly to install than pile foundations.
- Placement of additional fill to create a suitable grade transition according to roadway geometric design requirements may increase the pore-water pressures within the fine-grained subsurface soils. Any fill placement must consider the need to prevent increased pore pressures from decreasing the resistance of the soil mass to movement and the potential for reducing the stability of the landfill slopes. Since the increased pore pressures would be expected to dissipate after a given time, mitigative measures could include placement of the fill in controlled layers over time.
- Cutting of the waste to achieve a balance between fill height and slope stability may be required.
- Subsurface foundation improvement will likely be required to mitigate future compression of the waste mass. Mechanical foundation improvements may include 1) preloading of the area using excess soil to compress the waste or 2) deep dynamic compaction of the waste by dropping of a heavy weight onto the ground from a crane. In-situ ground improvements may include construction of stone columns. There are precedents for roadways over landfills that used these techniques. Several are summarized in section 4.3.
- Long-term monitoring and maintenance of the roadway will be required to address impacts of settlement on the performance of the road surface.

At-grade foundations are contemplated at Fresh Kills for roads aligned over the landfill, with preloading, placed in controlled lifts, as the likely means of expediting primary settlement.

4.1.2 Construction Over Waste Mound Perimeter Features

Construction of the on-landfill or service road alignments over the waste mound perimeter features will need to consider the following issues:

- Maintaining integrity of the cut-off wall;
- Maintaining leachate collection system performance;
- Maintaining access to the landfill infrastructure features served by perimeter service road;
- Separation between the landfill service road and park roadway.
- Minimum vertical clearance at grade separated crossings between the park road alignment and the service road, considering the need for landfill maintenance equipment size and height.
- The rise of the roadway from the off-landfill area onto the top of the waste mound will require analysis of the landfill side slope stability and settlement.

4.1.3 Conflicts with Landfill System Infrastructure

Many landfill infrastructure features will be impacted by construction of a roadway on the landfill. The infrastructure features will each need to be accommodated to maintain the landfill's environmental protection systems. Landfill infrastructure components that will need to be considered are identified in the following list.

- Landfill gas extraction wells and vents;
- Landfill gas lateral and header pipes;
- Landfill gas condensate traps;
- Landfill gas condensate drip legs;
- Stormwater management channels;
- Site access roads;
- Underground fire water line utility; and
- Overhead electric utilities

To develop roadways along the on-landfill alignments, settlement calculations would be completed to predict the amount of deformation of the landfill gas lines and stormwater management channels for potential grade reversal. Pipe crushing and stability calculations would be performed in assessing and redesigning landfill gas infrastructure. The design would provide details for modifying these features so that they can fulfill their design function during and after the predicted settlement occurs.

4.2 Landfill Design and Monitoring Criteria for Roads

As mentioned in section 2.2.3, the New York State Subpart 360 Landfill Regulations do not contain either design criteria or a required methodology for design of roadways over landfills. Consequently the design of the Fresh Kills Park roads will be developed to avoid compromising the function or integrity of the existing landfill environmental control systems and to maintain protection of the environment consistent with the level of protection provided under permit and permit equivalent requirements for the landfill.

The design will include a plan for systematic monitoring of construction activities, to document that the construction is consistent with the design, and a plan for post-construction monitoring to document the long-term integrity of the landfill environmental control systems that may be influenced by the presence of the roadway. The design will likely also include field demonstrations and measurements to verify design concepts and material parameters during the design process.

The design team understands that to meet the performance standard described, the road design will need to address concerns and possible methods of addressing them as presented below.

- *The cut-off wall and leachate collection trench, which contain and collect leachate (i.e., water that has come in contact with waste), must not be damaged or disturbed.* Consequently, a detailed plan for monitoring construction activities will be prepared. Prior to construction, monitoring instruments to measure lateral deformation of the soils directly adjacent to the cut-off wall and leachate collection trench will be installed. The instruments will be monitored prior to construction to establish a baseline condition and then monitored during and following construction to identify any changes from the baseline condition.

- *The continuity of the geosynthetic landfill cap and natural soil liner, which control infiltration of rainwater into the waste mass from above and exfiltration of leachate through the base of the landfill, must be maintained to prevent generation of additional leachate or release of leachate.* The NYSDEC has indicated that the adequacy of the road design will be critically reviewed with respect to maintenance of the continuity of these two features. Therefore, to assure that the NYSDEC concerns are addressed, the design team intends to construct and monitor a field-scale demonstration of the design concepts. A report of the monitoring results will be prepared and presented to NYSDEC for review and approval prior to completion of the final design.
- *The stability of the landfill and roadway embankments must be evaluated to demonstrate that the factor of safety against failure of the embankments meets the requirements of the New York State Subpart 360 landfill regulations for both static and seismic loading.* The analyses must consider the location of the cut-off wall and in-situ soil strength characteristics.
- Foundation improvement accomplished by deep dynamic compaction (DDC), which is accomplished by repeatedly dropping a heavy weight from a crane onto the ground to induce compaction of the foundation material, may damage landfill infrastructure. *Landfill infrastructure affected by the DDC will need to be rebuilt.*
- *The dynamic loading of the landfill foundation by vehicles traveling on the roadway must be considered as part of the design.*
- *A specific plan for monitoring the landfill environmental control features following construction must be prepared.*

The Fresh Kills Park road design will be prepared and presented to the NYSDEC in a design package formatted in a manner similar to that required for a landfill permit application (i.e., New York State Regulations, Subpart 360-2.3). The design package is anticipated to include five primary documents. A brief description of each anticipated document is provided in the following paragraphs.

- **Geotechnical Investigation Report.** The Geotechnical Investigation Report will be prepared using a combination of data obtained from historic site-specific investigations and supplemental data collected during the current road design process. The purpose of the report will be to establish the basis of geotechnical parameters used for road design and analysis.
- **Report of Field Demonstration of Pile and Natural Soil Liner Compatibility.** This report will be prepared based on data collected from field-scale tests of water seepage between piles and the on-site natural soil liner. The purpose of this report will be to demonstrate to NYSDEC that penetration of the landfill natural soil liner by piles will not decrease the effectiveness of the natural soil liner in containing leachate. The design team understands that this report and the associated field demonstration are necessary to provide NYSDEC with information to make a decision regarding the permissibility of installing piles through the landfill to support road infrastructure features.
- **Engineering Design Report.** The Engineering Design Report will be prepared to present design calculations, drawings, and specifications in support of the road design. The primary purpose of this report will be to present engineering analyses that demonstrate conformance with the requirements

of applicable permit and permit equivalent documents. A draft outline of the Engineering Design Report is provided in the Appendix.

- **Construction Quality Assurance Plan.** A Construction Quality Assurance Plan will be prepared that describes monitoring and documentation that will be provided during construction of the roadway features. The purpose of this plan will be to provide a systematic procedure for documenting that construction conforms to the intent of the design and that the integrity of the existing landfill environmental control systems and infrastructure are not compromised during construction.
- **Operation and Maintenance Plan.** An Operation and Maintenance Plan will be prepared that establishes the post-construction monitoring routine for the roadway and landfill environmental control systems. The purpose of this plan will be to provide a systematic procedure for monitoring and documenting the integrity of the landfill environmental control systems under service conditions. At a minimum, the plan will provide for monitoring of the landfill cover geomembrane integrity at the interface with roadway foundation structures, monitoring the deformation of the geomembrane beneath roadway embankment fills, monitoring of the leachate containment cutoff wall for deformation, monitoring of the landfill gas system components, and monitoring of the final cover system for soil erosion.

A preliminary draft table of contents of the roads design package Engineering Report for submission to NYSDEC is included in the Appendix to provide some insight into its content.

4.3 Case Study of Eastern Alignment at Yukon Saddle

4.3.1 Overview

During design of the roadway, the team will assess each segment for potential conflicts that require resolution. For each segment, the three categories of technical issues presented in Section 4.1 (i.e., foundations, perimeter features, and conflicts with infrastructure features) will be evaluated. For this preliminary feasibility report, the team has selected one key area of the eastern alignment for conceptual evaluation. The purpose of this case study is to identify key issues, present candidate resolutions, and identify features that need further evaluation.

The eastern roadway alignment is shown on Figures P-1 through P-3. The key area addressed in this case study is climb onto Mound 6/7 near Yukon Avenue, referred to as the Yukon saddle. In general, the conceptual location of the road along the Yukon saddle has been selected because it provides a relatively clear alley that minimizes interactions with existing landfill infrastructure. Nonetheless, there are still several conflicts that need to be addressed to demonstrate the feasibility of constructing a road in this area.

Preliminary discussion of possible conflicts and some potential solutions are presented below.

4.3.2 Roadway Alignment and Stormwater Management Basin Interaction

The layout of the proposed roadway at the approach to the Yukon Saddle appears on Figure P-2. In this area, the proposed roadway alignment is turning westward from the berm along Richmond Avenue towards the landfill mound, rising in elevation at an approximate grade of 5 percent, onto the landfill sideslope and saddle crest. An embankment fill, reaching a height 25 to 30 feet above existing grade, is tentatively

proposed as the roadway foundation at this location. The embankment fill would occupy a portion of existing stormwater management basin B-1, which would reduce the available storage capacity of the basin and block the flow of water between existing basins B-1 and B-2. However, because Basin B-1 appears to be over-sized compared to the stormwater management needs of the park, it is anticipated that re-analysis of the receiving watershed and redesign of the basin outlet structure will show that the basin can tolerate all or most of the proposed embankment. Re-establishment of flow between basins B-1 and B-2 would be accomplished by installation of a culvert beneath the embankment fill.

Stability of the embankment against slope failure due to relatively weak recent clay and silt deposit subsurface foundation soils would be provided by a combination of the following design or construction features: 1) design of the embankment sideslopes at a maximum inclination of 33 percent; 2) construction of the embankment in stages to allow for consolidation and resulting strength gain of weak foundation soils; 3) field monitoring of the embankment fill for movement using inclinometers and monitoring of the in-situ pore water pressure changes; 4) foundation improvement by excavation and replacement of unacceptable material, construction of mechanically stabilized embankment (e.g., using geogrid or high-strength geotextile foundation reinforcement), or lateral load supporting pile foundation and 5) use of lightweight embankment backfill such as Styrofoam blocks to reduce the load.

4.3.3 Roadway Alignment and Landfill Perimeter Feature Interaction

As the roadway alignment leaves Basin B-1 and extends towards the landfill, the proposed roadway alignment crosses over the landfill perimeter infrastructure, which includes the following features, generally illustrated on Figure P-2 and at the bottom of Figure YC-1. (Additional features are addressed in Section 4.2.4):

- perimeter service road;
- landfill geomembrane cover;
- leachate containment cutoff wall; and
- leachate collection trench and leachate header line.

To accommodate both the roadway alignment and landfill infrastructure at this critical crossing, the following three potential design strategies have been identified for further consideration: 1) extension of the earthen embankment; 2) construction of cantilevered bridge; and 3) construction of a span bridge with abutments at each end (as shown on Figure YC-1). To minimize the fill associated with matching the grade between the landfill and approaching roadway, minor excavation through the existing landfill perimeter swales and potentially into waste (which the team understands may consist of slag material within the 'Yukon saddle' portion of landfill section 6/7) would be considered as part of the design strategy. The three strategies are explored in the following paragraphs.

Design Strategy 1. Continuation of the Earthen Embankment. The following list presents design and operations issues associated with continuation of the earthen berm over the existing landfill perimeter infrastructure and potential resolution strategies.

- *Perimeter Access for Landfill Service Vehicles.* Access along the perimeter of the landfill could be provided by redirecting the service road laterally around the embankment to the location where the park road and access road could cross at grade. This would involve three new turns in the service road and an at-grade crossing with road traffic. The latter is undesirable since the service road is also intended to serve as a park path.

- *Stability of the Landfill and Berm Sideslope.* Stability of the embankment against slope failure would be addressed using the same techniques proposed for embankment fill over the stormwater management Basin B-1 (i.e., embankment sideslopes at a maximum inclination of 33 percent; construction of the embankment in stages to allow for consolidation of weak soils; and monitoring of the embankment fill for movement, foundation improvement, or use of lightweight backfill).
- *Stability of the Leachate Cutoff Wall.* Compression or settlement of the leachate cutoff wall due to placement of an embankment berm could be addressed by construction of a rigid cover to protect the top of the cutoff wall against compression. A design similar to that has been used to create truck crossings at landfill mounds 1/9 and 6/7, but suited to the greater than the loads imposed by the embankment and road traffic.
- *Stability of the Leachate Collection Trench.* Stability of the gravel-filled leachate collection trench due to placement of an embankment berm is not expected to be an issue because the trench is filled with non-compressible material. However, the potential for crushing the leachate header line must be considered. Possible methods of protecting the leachate header pipe could include construction of a rigid structure above, or a heavy duty sleeve around the pipe to deflect the loads from the header pipe.
- *Stability of the Geomembrane Cover.* Strain within the geomembrane cover caused by increased settlement under the center of the berm would need to be addressed by minimizing the applied loads to reduce settlement beneath the embankment. Geomembrane strain due to settlement of the foundation would be evaluated with the goal of demonstrating that strain would be less (with an appropriate factor of safety) than yield stress/strain for the parent HDPE geomembrane and seams.

Although it appears that the design and operation issues identified above can likely be resolved the resulting road alignment and at-grade intersection may not be preferable. This design strategy is considered to have potential for further exploration should other strategies prove ineffective.

Design Strategy 2, Construction of a Cantilevered Bridge. The primary advantage of this strategy is that the perimeter service road/park path would not intersect the park drive road at grade but, rather, pass underneath the park drive. The following list presents design and operations issues, and possible resolutions, associated with construction of a cantilevered bridge over the existing landfill perimeter infrastructure. The cantilevered structure would be founded on piles located outside of the existing cutoff wall and the bridge portion of the roadway would extend from the piles to the landfill sideslope of the west of the piles.

- *Pile Foundation Construction.* The type of piles and installation methods used could influence the cutoff wall and, therefore, it is necessary to maintain a minimum offset distance between the piles and the wall. Based on preliminary evaluations and the experience of the team, for preliminary design purposes, it is suggested that driven piles be constructed no closer than 15 ft to the cutoff wall and that drilled piles not be constructed any closer than about 5 to 10 ft from the cutoff wall. Analysis of cutoff-wall deformation or movement using both analytical finite element methods would be performed to evaluate the potential for pile installation to damage the cutoff wall if this strategy is carried forward to future phases of design.

- *Cantilever Touchdown at the Existing Landfill.* The connection of the cantilever span with the existing landfill slope would need to be evaluated and allowances for settlement incorporated into the design. However, through foundation improvement techniques, such as deep dynamic compaction, surcharging, or stone columns, it is expected that settlements can be accommodated.
- *Perimeter Service Road.* The existing perimeter service road would be maintained in its current location under this design strategy. However, a minimum clearance based on the maximum landfill service vehicle height would need to be maintained.

The disadvantage of this strategy is that the curvature of the road, combined with the angle at which the park road passes over the service road, cause the cantilever structure to become massive and complex, and out of proportion with the scale and with the purpose of the crossing and its setting. Therefore, Design Strategy 2 would be considered only in the absence of more effective solutions.

Design Strategy 3, Construction of a Span Bridge. This strategy provides for a grade separated crossing with a more effective structure. The following list identifies design and operations issues, and potential resolutions, associated with construction of a bridge overtop of the existing landfill perimeter infrastructure. The bridge would be founded on pile-supported abutments at both ends. One abutment would be located completely outside the landfill, but three options are under consideration for the placement of the abutment closest to the landfill mound, as shown by Figs. YC-1, 2 and 3. Given the underlying soil conditions, the abutments must be supported by piles. Therefore, this condition would be one of those where the use of piles inside the cutoff wall would be considered, on an exception basis.

- *Pile Foundation Construction.* Pile foundation construction outside of the leachate cutoff wall would address the considerations described for cantilevered bridge foundation. Pile foundation construction inside of the leachate cutoff wall would require establishment of minimum off-sets from the leachate collection trench. As guidance, it would be suggested that drilled and driven piles not be constructed any closer than 5 to 10 feet away from the leachate collection trench.

The waste thickness at this location is estimated to be approximately 20 feet based on boring IT-178S as presented in the 1993 Hydrogeologic report and as confirmed by the as-built depth of the cutoff wall at this location. With an estimated abutment backfill height of about 25 ft, the waste would be expected to settle on the order of 1 ft to 1.5 ft based on an analysis of waste settlement data collected by Geosyntec from a settlement investigation of a landfill in the southeastern United States. (See Appendix B for further information.) A combination of methods would be considered for minimizing foundation settlement to reduce the potential for separation of the cap-pile connection and to minimize the need for maintenance of the roadway. To minimize settlement impacts, the bridge abutment foundation would be treated (e.g., preloading, and/or excavation and replacement of foundation materials) to reduce short term, long-term and differential settlement (near the pile foundation).

- *Pile and Geomembrane Cap Connection and Monitoring.* Continuity of the landfill cover system at pile foundation locations is an issue that would need to be addressed for piles constructed inside of the leachate cutoff wall. A typical detail for the boot connection is shown on Figure YC-3.
- *Pile Impacts to Landfill Foundation.* The condition of the piles at the bottom of the landfill would need to be considered. Because the landfill has a natural soil liner instead of a flexible membrane liner,

connection between the pile and liner is not an issue. However, the design of the piles would need to prevent vertical migration of leachate from the landfill. This will be addressed during the next phases of design.

- *Settlement in Pile Location.* At the edges of the landfill, foundation improvement techniques, such as stone columns or removal and replacement of waste material with competent soils, could be used to reduce the future settlement of the waste surrounding the piles. A boot system as described in the bullets above would be feasible, and would be designed such that monitoring and future maintenance of the pile could be performed.
- *Stability.* Stability of the landfill slopes due to soil fill behind the bridge abutments would be addressed using the same techniques proposed for embankment fill over the stormwater management Basin B-1 in Strategy 1. It is estimated that a fill height of 25 to 30 feet is necessary to backfill behind the abutments.

This strategy appears to offer the most favorable opportunities for effective, workable design of the roadway, with option YC-1 providing the most efficient roadway design, and option X-3 the least efficient. The primary differentiation among Options YC-1, YC-2 and X-3 is the placement of the pile-supported western abutment, and its implications for the landfill cover seal.

The choice among options is dependant upon the design team's ability to demonstrate that the selected design will not compromise the landfill environmental control systems to the satisfaction of the NYSDEC. As an additional step in making that demonstration, and to provide an indication of how the design process will continue to evolve, Option YC-1 was further developed as Figure YC-1.1 to include a detail of how visual and physical access to the boot seal may be provided at the pile foundation inside the cutoff wall. The same concept would be applicable to Option YC-2.

4.3.4 Roadway Alignment and Landfill Infrastructure Interaction

The conceptual typical section for the roadway traversing the mound along the Yukon saddle is shown on Figure TS-2. As the location where the roadway alignment transitions onto the landfill surface, the roadway impacts the following landfill infrastructure features: 1) firewater transmission pipe leading to the Section 6/7 flare station; 2) existing landfill gas header and condensate lines; and 3) proposed stormwater drainage swales. To accommodate the interaction between these landfill features and the roadway alignment the following design considerations could be made.

- The alignment crosses the firewater transmission line. The line would be evaluated for resistance to crushing and potential settlement along the alignment calculated to analyze the need for protection. If feasible the line would be left in place. Alternatively, the firewater line could be to a more favorable roadway crossing location.
- The existing landfill gas header and condensate lines could be disconnected and reinstalled within a carrier pipe that is designed to withstand the traffic and embankment fill loads imposed by the roadway. The carrier pipe would be located below the final cover geomembrane along with the other landfill gas header and lateral pipes at the south end of Section 6/7. Settlement of the alignment would be checked to verify that the pipes would continue to provide positive drainage of condensate to the condensate traps after settlement.

- At locations that conflict with proposed stormwater swales, alternative routing stormwater would be incorporated into the final grading plans.
- Overhead electric utility lines would be relocated away from the roadway alignment and preferably buried within the landfill protective cover soil beyond the limits of any fill required for roadway construction.

4.3.5 Roadway Alignment and Landfill Cap

Although implementation of the roadway design strategies discussed in this section would be more easily accommodated if roadway construction is performed prior or concurrent with landfill capping. Roadway construction can be performed by removal and reconstruction of the landfill cover.

4.3.6 Eastern Alignment Case Study Conclusion

The results of the study to date suggest that a roadway alignment in the eastern corridor and along the Yukon saddle is viable. Further analysis will be performed to evaluate settlement of specific infrastructure elements and the stability of embankments and refine the alignment and crossings, horizontally and vertically. A program of in-situ explorations is being developed to inform the analyses.

4.4 Case Study of Southern Alignment

4.4.1 Overview

The southern roadway alignment at the Forest Hill Road traversal of the south end of landfill section 6/7, shown on Figures P4 and P5, is another area that will require careful design consideration if that alignment is chosen. The conceptual location of the road at this location has been selected to minimize conflict with existing landfill infrastructure; however, there remain a number of interactions that must be resolved. Discussions of the potential conflicts, alternatives, and resolutions are presented in this section by reviewing the road alignment from east to west.

4.4.2 Roadway Alignment between Forest Hill Road and Landfill Mound 6/7

The roadway alignment between Forest Hill Road and landfill section 6/7 will cut through the existing berm that parallels Richmond Avenue, cross the existing wetland areas, and rise over the landfill service road, perimeter features, and southern crest of mound 6/7, and continue to the confluence loop generally along a mound shelf. Because the wetlands are a valued long-term resource, to be protected and improved, the crossing between the berm and the mound is envisioned as a viaduct that passes over, rather than an embankment that divides the wetland space.

4.4.3 Perimeter Service Road and Mound Slope Interface

Strategies for design and interaction of the roadway with landfill perimeter features up to the point where the roadway reaches the landfill crest will adhere to those outlined for Yukon. These strategies include construction of an embankment, cantilevered bridge or simply supported bridge over the perimeter landfill features. The bridge span with two abutments is the preferred approach. Figures FC-1, FC-2 and FC-3

present three possible treatments of the simple span, corresponding to Options YC-1, YC-2 and YC-3 at Yukon. Of the three, option FC-1 offers the most efficient and Option FC-3 the least efficient roadway designs. The conceptual boot access concept shown in Figure YC-1.1 would can be adapted to Options FC-1 and FC-2 as well, and the choice among the options is dependent on the design team's ability demonstrate that the selected design will not compromise the landfill environmental control systems to the satisfaction of the NYSDEC.

4.4.4 Roadway Alignment and Landfill Infrastructure Interaction

The conceptual typical section for the roadway traversing landfill section 6/7 along its southern shoulder is shown on Figure TS-3. Continuing from the southern crest of the landfill, the roadway will intersect stormwater drainage channels, LFG gas vents, LFG extraction wells, LFG lateral and header conveyance pipes. The design of the roadway will provide new drainage paths parallel to the roadway and suitably placed culvert crossings. To the extent possible, drainage areas and flow patterns will continue to match proposed post-closure conditions. The slopes of the channels will be designed in anticipation of settlement of the landfill. However, because some type of foundation improvement is anticipated for support the roadway design, channel slopes would not be expected to change significantly.

At the intersection of the roadway with the landfill gas header and lateral pipes, the existing pipes would be abandoned to facilitate foundation improvement construction. As part of the abandonment construction sequence, temporary above-grade connections would be installed to maintain the functionality of the system. Following foundation improvement new header and lateral connection pipes would be installed below grade. Where the roadway alignment intersects with gas extraction wells or vents, these features would also be abandoned during foundation improvement. Following foundation improvement construction, new landfill gas extraction wells and vents would be installed in nearby locations. Additional wells and vents could be established to compensate for the relocation of the abandoned features. Although not anticipated, condensate knockout and pump station locations could also be abandoned and relocated if necessary. Service vehicle access to each of the condensate knockout and pump station locations would be incorporated into the roadway design.

4.4.5 Roadway Alignment Foundation

Alignment of the roadway along the southern crest of landfill Section 6/7 would require evaluation of the stability of the waste slope and foundation improvements such as surcharging, deep dynamic compaction, or stone columns, as described for the crossing along the Yukon saddle.

APPENDIX A

REVIEW OF LITERATURE ON ROADWAYS OVER LANDFILLS

To provide additional information on foundation improvement techniques and the performance of roadways over landfill, five precedents of highways over landfills found in the literature were reviewed and summarized. A field study that investigated settlement of waste due to surcharge loads, which was performed by Geosyntec at a landfill in Tennessee, is also summarized (copies of the reference documents can be provided upon request). Implications of these case studies to the Fresh Kills Park Road design are as follows:

- Older waste deposits, which occur along the Yukon saddle and along the southern corridor, are anticipated to experience less settlement than newer waste deposits.
- Roadways constructed on foundations that were improved have provided 12 to 14 years of service life before requiring resurfacing.
- Dynamic compaction of waste can significantly reduce the volume of the waste beneath the roadway and, accordingly, the amount of settlement that would occur during the service life of the road. However, due to the existing landfill infrastructure at Fresh Kills, dynamic compaction techniques may be of limited use at Fresh Kills. The suitability of dynamic compaction will be evaluated during the next design stage and will consider the potential for damage to infrastructure features (e.g., landfill gas wells, condensate traps, leachate collection trenches, etc.), the benefits to roadway performance, and whether the benefits of dynamic compaction warrant the cost to reinstall damaged infrastructure.
- Primary settlement of waste due to static pre-loading occurs rapidly, on the order of only months which, if chosen, will aid construction scheduling for the Fresh kills park road project. However, secondary settlement is not affected by pre-loading or dynamic compaction and must be accounted for in the design and maintenance for the roadway.

1. Interchange of New Jersey Route 18 and Route 36, New Jersey

The alignment of the roadways and connector ramps for the interchange at the intersection of New Jersey Route 18 with the Garden State Parkway and New Jersey Route 36 traverse the Tinton Landfill (Lewis and Langer, 1994). The Tinton landfill received municipal waste and ceased operation in the early 1970s. The landfill was covered with soil and overgrown vegetation at the time of roadway construction. The highway embankments for the interchange at the landfill reach heights of 10 to 29.5 ft. Waste at the interchange location is as deep as 25 ft and is underlain by medium dense to dense silty sand. The amount of primary settlement of the landfill surface under the embankment loads was estimated to be on the order of 5 to 6.9 ft without the application of ground improvement.

Three different approaches were considered to minimize the settlement and the possibility of bearing capacity failure: 1) removal of the waste and replacement with adequate fill, 2) preloading of the waste; and (3) deep dynamic compaction (DDC) of the landfill followed by a short period of preloading. It was decided that removal of the waste was too expensive and that preloading would not reduce post-construction settlements to an acceptable range unless a long preloading period was used (on the order of several years). The method selected for ground improvement was DDC of the waste material followed by a short period of preloading (six months). DDC was designed largely based on the Federal Highway Administration (FHWA) Report No. FHWA/RD-86/133, "Dynamic Compaction of Highway Construction – Volume I: Design

and Construction Guidelines". Details of the DDC process used at the Tinton landfill are reported by Lewis and Langer (1994).

The DDC processes resulted in up to 50% reduction in waste thickness. A test embankment was constructed on a landfill section with no DDC for comparison purposes. The test embankment was preloaded with a 5 ft surcharge for a period of 6 months. Settlements of both embankments were monitored for a period of 4 years. Lewis and Langer reported that the embankment on non-dynamically compacted waste experienced a larger total settlement than the embankment on dynamically compacted waste. However, primary settlement of the embankment on non-dynamically compacted waste occurred in a short period of time and may be considered "immediate". Long-term settlement of both embankments was reported to continue beyond the reporting period and was similar in magnitude for both embankments

2. State Highway 11, Tulsa, Oklahoma

Snethen and Homan (1991) reported on the construction and performance of a portion of the Gilcrease Expressway, Tulsa, Oklahoma, that crosses a strip mine and uncontrolled landfill area. The Gilcrease Expressway is an extension of State Highway 11 (SH-11) which connects the Tulsa International Airport with Highway U.S. 75. Near Yale Avenue, the highway crosses an area that was strip mined and then subsequently used as an uncontrolled sanitary landfill. The project involved construction of an embankment having a maximum height of 29.5 ft on layers of mine spoil covering layers of trash. The trash thickness ranged from 6 ft to 23 ft.

Several options were considered for ground improvement, including DDC, grouting, and constructing an elevated roadway founded on drilled shafts reaching competent shale. DDC was selected on the basis of feasibility and economy. ODOT required three instrumented test sections to evaluate the effectiveness of ground improvement. Details of the DDC process used are reported by Snethen and Homan (1991). The results of the DDC were inconsistent and raised concern about its effectiveness. Therefore stone columns installed using deep dynamic compaction were used at critical locations within the site. Three test stone columns were installed to determine the most effective construction operation. Details of the construction process for the three test stone columns are reported by Snethen and Homan (1991).

The selected construction process was used to install 95 stone columns having 6 ft diameter and 16 ft deep. After construction of the stone columns DDC was completed on the remaining portions of the site. ODOT monitored the settlement of the embankment constructed on the improved ground. Data collected after two years following the construction of the embankment indicated 0.3-ft of settlement at areas improved using stone columns and 0.5-ft of settlement at areas improved using DDC. Snethen and Homan (1991) recommended using test sections to determine the effectiveness and construction sequence of DDC as well as to assess the need for additional foundation support.

3. Interstate 85, New Jersey

Interstate 85 is approximately 3,200 ft long and is located in northern New Jersey. The highway connects the eastern end of Interstate 280 to the Newark-Jersey City section of the New Jersey Turnpike. The highway was constructed on a sanitary landfill containing 5- to 15-year old residential and industrial waste (Burlingame, 1985). The waste thickness ranged from 6 to 30 ft and is underlain in some areas by up to 8 ft of organic silt and peat followed by dense sand. Heavy rolling, removal and replacement, and surcharging were each considered for foundation improvement. DDC was a new construction technique at the time of construction and was not considered. Heavy rolling was considered not sufficiently effective, and removal

and replacement was not cost-effective. Therefore surcharging and a staged construction scheme were selected.

The landfill was stabilized by placing a 6.8-ft thick pad of granular fill followed by surcharging with a 6-ft thick embankment for a period of 1 to 2 years. The surcharging was designed to cause settlement equivalent to estimated primary and secondary settlements due to embankment loads after 10 years from construction. The time for primary settlement to occur under the surcharge load was approximately 12 months. Burlingame (1985) reported large variations in settlement magnitudes at locations of equal waste thickness with higher variability at thicker waste locations. No secondary settlement was measured 3 years after the road was constructed, but heave on the order of 0.02 ft to 0.04 ft was measured at locations. Visual inspections of the roadway 3 years after it was opened to traffic revealed the pavement was structurally sound and showed no signs of distress.

4. Route 71, Arkansas

Arkansas State Highway and Transportation Department (ASHTD) realigned Route 71, north of Fayetteville, Arkansas, in the late 1970s and early 1980s to a location where the highway crossed a closed sanitary landfill (Welsh, 1983). The landfill varied in depth between 18 and 36 ft including a 3 ft clay cover. ASHTD together with FHWA decided to use DDC for ground improvement to reduce the post-construction settlement of waste underneath the highway embankment. Prior to ground improvement, a 4.5 ft thick layer of coarse granular material was placed over the landfill site to support the DDC crane, minimize localized settlement, and to provide additional separation from the waste. Details of the DDC process carried out by the contractor are provided by Welsh (1983).

The DDC process resulted in about 20% to 25% compression of the sanitary landfill thickness. Load tests were performed on the landfill waste before and after stabilization of the waste. A pile of fill 16 ft high and 36 ft in diameter was used to load the fill. Measured settlement of the waste tested prior to stabilization and after 7 days of loading was 0.46 ft, while settlement of the stabilized waste was 0.95 ft. Welsh anticipated that the consolidation of the waste using DDC would slow down the rate of waste decomposition which would result in slow and gradual long-term settlement that should not substantially affect the operation of the roadway. The highway was completed and opened to traffic in December of 1984. In 1985, ASHTD reported one major area of settlement but the settlement was not deemed noticeable and no corrective measures were necessary (Blacklock, 1987).

5. Two New York highways on refuse fill

According to Burlingame (1985) the New York State Department of Transportation (NYSDOT) constructed at least two highways on refuse fills. The first highway was constructed on relatively young refuse having a thickness ranging from 5 to 25-ft. The second highway was constructed on older refuse (20 years old) having a thickness of about 40-ft. Heavy rolling was used to stabilize the refuse on two stages for both projects using a heavier compactor in the second stage. Densification was reported to extend to a depth of about 10-ft as indicated from electrical resistivity surveys. The first highway experienced large differential settlements and required resurfacing after 12 years in service. The second highway was successful and showed good serviceability after 14 years in service. The difference in performance was attributed to the age of the refuse (Burlingame, 1985).

6. Waste Settlement Analysis Project

A comprehensive assessment was performed by Bachus, Zettler, and Fleming in 2004 of the primary and secondary waste compression characteristics of an existing 60-foot deep waste deposit at a municipal waste landfill near Memphis, Tennessee. The evaluation was not related to a roadway development project but, instead, was intended to evaluate only waste settlement properties resulting from construction of overlying fills and was originally published by ASCE in the Proceeding for GeoCongress 2006, Atlanta, GA. The waste at the landfill was relatively new (i.e., between about 5 and 10 years old). To obtain in situ waste compression parameters, an instrumented 10.4-acre test fill was constructed, fully instrumented, and monitored over an approximately 6-month long time period. To compliment conventional surface and buried settlement plates, a horizontal settlement profiling system was developed to facilitate settlement evaluations at 1-foot horizontal intervals along four transects at the base of the test fill.

The results of the study indicated that, although there was significant total settlement across the study area, there was only a modest amount of differential settlement. The rate of primary settlement was observed to be rapid, occurring within a matter of weeks. Secondary compression of the waste was also monitored. The initial results of secondary compression monitoring will be published in September 2007. A key implication of this study to the Fresh Kills Park Road design is that the duration of preloading is anticipated to be short (i.e., a few months) and would not be expected interfere with other closure construction sequencing.

APPENDIX B

The following outline presents the preliminary draft table of contents of the roads design package Engineering Report for submission to NYSDEC.

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