THE PORT AUTHORITY OF NY & NJ

Engineering Department

Civil Design Guidelines

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TABLE OF CONTENTS

1.0 CIVIL DISCIPLINE OVERVIEW

These guidelines are provided as an overview of the Port Authority of New York and New Jersey's (PANYNJ) design standards. Design details and associated documents outlined in these documents will be provided to the respective client.

The elements of design or criteria outlined herein are by no means an exhaustive study of all relevant items necessary to design the various civil elements of a project and must be used in conjunction with the appropriate codes (whether referenced or not), and the PANYNJ Standard Details and Technical Specifications. Instead, the purpose is to establish a uniform approach to the design of the "civil" elements common to all of the PANYNJ facilities. Where a particular situation is not covered, the use of good engineering judgment and principles is required and should prevail.

The Guidelines shall not replace professional design analyses nor are the Guidelines intended to limit innovative design where equal performance in value, safety, and maintenance economy can be demonstrated. The design team shall be responsible for producing designs that comply with the Guidelines in addition to all applicable codes, ordinances, statutes, rules, regulations, and laws. Any conflict between the Guidelines and an applicable code, ordinance, statute, rule, regulation, and/or law shall be addressed with the respective functional chief. The use and inclusion of the Guidelines, specifications, or example drawing details as part of the Contract Documents does not alleviate the design professional from their responsibilities or legal liability for any Contract Documents they create. It is also recognized that the Guidelines are not universally applicable to every project. There may be instances where a guideline may not be appropriate. If the design professional believes that a deviation from the Guidelines is warranted, such a deviation shall be submitted in writing for approval to the respective functional chief.

2.0 DESIGN CRITERIA AND SPECIAL REQUIREMENTS

2.1 ELEMENTS OF DESIGN FOR ROADWAYS

2.1.1 GENERAL

Basic layout shall conform to the Facility Master plan and/or approved functional drawings.

Elements of design, such as the number and width of travel lanes and shoulders, parking aisle and space dimensions, roadway type and classifications, design speed, traffic volumes, stopping and passing sight distances, etc., shall be developed as noted herein and conform to the latest version of American Association of State Highway and Transportation Officials' (AASHTO) "A Policy on Geometric Design of Highways and Streets" (the Green Book).

The appropriate use of other published design criteria and guidance such as that published by the Federal Highway Administration (FHWA), Transportation Research Board, Institute of Transportation Engineers, or the National Association of City Transportation Officials (NACTO), that supplement or expand on existing AASHTO guides in designing highways and streets, particularly those in low-speed urban streets should be considered. The NACTO Urban Street Design Guide can be a good resource for design of urban streets.

When the limits of a particular project affect or overlap with roadways not under the jurisdiction of the PANYNJ, adjust the elements of design as necessary to conform to the elements of design or criteria for the agency having jurisdiction.

In addition to the Green Book, the following AASHTO publications, in their current version, shall be used in conjunction with this manual:

- Roadside Design Guide (RDG).
- Guide for the Development of Bicycle Facilities (Bike Guide).
- Guide for the Planning, Design and Operation of Pedestrian Facilities.

Unless otherwise noted, all references to "Tables," "Figures," or "Chapters" herein, are found in the Green Book (AASHTO 2011, 6th Edition).

The New Jersey Administrative Code Section 7:13-11.6 requires that the travel surface of a public roadway be constructed at least one foot above the base flood elevation (BFE), unless it is not feasible and the road is constructed as close to the BFE plus one-foot elevation as possible. Refer to the Climate Resilience Design Guidelines [(1)] for BFE information.

2.1.2 CLASSIFICATIONS

Prior to developing the elements of design, it is necessary that roadway(s) be classified as per standard AASHTO classifications in the Green Book. The classification of the roadway(s) shall be established in conjunction with the Traffic Engineering discipline. The roadways under the jurisdiction of the PANYNJ generally fall under the following AASHTO "Urban" classifications:

- Principal Arterial—Serves as main movement.
- Minor Arterial—Interconnects principal arterials.
- Collectors—Connects local roads to arterials.
- Local Roads and Streets—Allows access to abutting land.

For more information or discussion on classifications see Chapter 1 of the Green Book and consult with the Traffic Engineering Discipline.

2.1.3 Geometric and Miscellaneous Elements

After classifying the roadway(s), establish the elements of design. These include design speed, sight distance, horizontal alignment, vertical alignment, and cross section elements such as cross slope, lane and shoulder widths, and sidewalk and pedestrian elements and curbs.

2.1.3.1 Design Speed

Design speed is a selected speed used to determine or establish the various geometric design features or characteristics of the roadway. The design speed shall be as established by the Traffic Engineering Discipline.

2.1.3.2 Sight Distance

Sight distance is the length of roadway visible to the operator of a vehicle ahead. An important element of design is to arrange the geometric elements such that adequate sight distance is provided. The following four types of sight distance shall be considered:

A. Stopping Sight Distance (SSD)

Stopping sight distance is the distance that enables a vehicle traveling at or near the design speed to come to a complete stop before a stationary object ahead and in its path. As appropriate, the following three types of SSD shall be evaluated. If conditions permit, consider providing greater SSD to increase the margin of safety.

1. Select appropriate SSD for horizontal curves as per Tables 3-1 and Figure 3-22b.
2. Adjust SSD values to compensate for the roadway grades as per Table 3-2.
3. Select appropriate SSD for crest vertical curves as per Table 3-34 and Figure 3-43.
4. Select appropriate SSD for sag vertical curves, as per Table 3-36 and Figure 3-44.

B. Decision Sight Distance (DSD)

Decision sight distance is the distance needed for the operator of a vehicle to detect and react when confronted with an unexpected or otherwise difficult to perceive information source or condition. DSD shall be evaluated at critical locations as follows:

1. At an interchange or intersection where unusual or unexpected maneuvers are required. For example, a gore at an exit ramp or a left-hand exit off the main roadway.
2. Changes in cross section such as toll plazas and lane drops.

Decision sight distance shall be established in conjunction with the Traffic Engineering Discipline and selected from Table 3-3.

C. Passing Sight Distance (PSD)

Passing sight distance is applicable only in the design of two-lane roadways (including two-way frontage roads). It is impractical to design crest vertical curves to provide for PSD.

1. Select appropriate PSD for horizontal curves as per Table 3-4.
2. Select appropriate PSD for crest vertical curves as per Table 3-35.

D. Sight Distance at Intersecting Roadways

The operator of a vehicle approaching an intersection should have an unobstructed view of the entire intersection and an adequate view of the intersecting roadway to permit control of the vehicle to avoid a collision. Select appropriate sight distance and sight triangle as per Chapter 9 of the Green Book.

2.1.3.3 HORIZONTAL ALIGNMENT

Once a design speed is established as per Paragraph 2.1.3.1, the horizontal alignment for the roadway can be designed. The design of the horizontal alignment for a roadway must consider the proper combination of horizontal curvature and cross slope, including superelevation. In no case shall the horizontal alignment for the roadway violate the minimum SSD as per Paragraph 2.1.3.2 A. The following shall also be considered:

1. When possible use a curve having a larger radius (flat curve) than the minimum selected as per Paragraph 2.1.3.3 A.
2. Where compound curves are used, the ratio of the curves respective radii should not exceed 1.5:1. For intersections or other turning roadways (such as loops, connections, and ramps), this ratio may be increased to 2:1. For additional discussion on compound curves, see Chapter 3 of the Green Book.
3. Avoid use of curves with small radius (sharp curve) following tangents or a series of flat curves. Sharp curves should be avoided on long or steep grades.
4. Reverse curves should include an intervening tangent section. Provide a length of the tangent between the reverse curves that is the sum of the superelevation transitions (i.e., superelevation runoff and tangent runout) calculated for each curve. For superelevation transition, see Paragraph 2.1.3.3 C.
5. Broken-back curves (two curves in the same direction connected with a short tangent) should not be used.
6. Horizontal alignment and its associated design speed should be consistent with other design features and topography.
7. Other than intersections or other turning roadways (such as loops, connections, and ramps), the minimum length for horizontal curves should be 15 times the design speed in miles per hour (MPH).

A. Curve Radius

1. The minimum radii of curves are important control values in designing for safe operation. Minimum radius is determined from the maximum rate of superelevation and the maximum side friction factor for design.
2. Establish minimum radius as per Tables 3-7 through 3-12b. Consider flatter curve if site conditions permit.
3. A curve is not required if two bisecting tangents would result in a curve having a central angle less than 30 minutes.

B. Superelevation

Superelevation is introduced as an element of design, and specifically in horizontal curves, to assist vehicles maneuver through areas of curvature.

There are practical limits to the rate of superelevation. High rates create steering problems for drivers traveling at lower speeds, particularly during ice or snow conditions. Lower maximum superelevation rates may be employed when adjacent buildings, lower design speeds, and frequent intersections are limiting factors. The following are desirable:

1. Urban arterials, collector roads and streets, local roads and streets: 4% maximum.
2. Interstates and urban freeways: 6% maximum.
3. Ramps: 6% maximum.

Select minimum required curve radius for design superelevation rates as per Tables 3-8 and 3-9.

C. Superelevation Transition

Superelevation transition is the term used to describe the length of roadway required to adjust the cross slope of the roadway, typically from a normal crown section, to the superelevated section (i.e., one direction) or vice versa. Superelevation transition in the roadway cross slope consists of superelevation runoff and tangent runout sections.

1. Select minimum required superelevation runoff length as per Table 3-17b.
2. Select minimum required tangent runout length as per Tables 3-17b; 2.0% row.
3. Superelevation runoff length with respect to Point of Curvature (PC) should be established as per Table 3-18.

D. Superelevation for Low-Speed Roadways

Although superelevation is advantageous, various factors often combine to make its use impractical in certain conditions, such as wide pavement area, surface drainage considerations, frequency of cross streets and driveways, or need to meet along an adjacent property or area. For this reason, superelevation is generally omitted for horizontal curves on low-speed roadways and centrifugal force is counteracted solely with side friction. Refer to Table 3-13b and Figure 3-14 for the relationship of superelevation, radius, and design speed.

E. Lane Transition/Taper

1. Based on the selected design speed, calculate the minimum required taper length as follows:

$$L = (V \text{ x } W) \quad \text{(for design speed greater than 40 MPH)}$$

$$L = \frac{(V^2 \text{ x } W)}{60} \quad \text{(for design speed less than 40 MPH)}$$

Where: V = Design speed (MPH)

W = Lane width reduction (feet)

L = Taper length (feet)

2. Where possible, use a taper length longer than the minimum as calculated in Paragraphs 3.1.3.3 E.1. and 3.1.3.3 E.3.
3. For auxiliary lanes, the taper rate may be 8:1 [longitudinal: transverse or L: T] for design speeds up to 30 MPH and 15:1 L: T for design speeds 31 to 50 MPH. Refer to Chapter 9 of the Green Book.
4. For taper and length of entrance and exit ramps, acceleration and deceleration lanes refer to Chapter 10 of the Green Book.

F. Width of Roadway

1. Establish the width of roadway based on the number and width of lanes, use of shoulders, use of median, etc.
2. In areas of curvature, it may be necessary to increase the width of the roadway. The additional width required is a function of the design vehicle, radius of curvature, and selected design speed. Select appropriate width as per Tables 3-28 and 3-29.

2.1.3.4 VERTICAL ALIGNMENT

A. When determining vertical alignment of the public roadway in a flood hazard area, the vertical elevation of the travel surface shall conform to the design flood elevation (DFE) as determined per guidance in the Climate Resilience Design Guidelines. If this is not feasible, the elevation of the travel surface of the roadway and parking lot shall be as close to the DFE as possible.

B. Horizontal and vertical alignments should complement each other.

C. Vertical alignment consists of longitudinal grades and vertical curves.

D. The selected design speed as well as existing site conditions, such as topography and subsurface conditions, shall be considered to establish the vertical alignment for the roadway.

E. The vertical alignment shall ensure that water resulting from rain or snow is properly removed from the roadway.

F. Alignment should be as flat as possible near intersections where sight distance is important.

G. Longitudinal or Profile Grade

1. Avoid frequent changes in profile grade.
2. Maximum profile grade for design speed up to 45 MPH is 5%.
3. Maximum profile grade for design speed greater than 45 MPH is 3 to 4%, depending on terrain.
4. Minimum profile grade is 0.50%.
5. Profile grades up to 1% steeper than the above respective values shown may be used if approved by the Chief Civil Engineer.

H. Vertical Curves

1. There are two types of vertical curves; crest vertical curve and sag vertical curve. The minimum length of a vertical curve (crest or sag) is established as follows:

$$L = KA$$

Where: L = Minimum length of vertical curve (feet)

A = Algebraic difference in longitudinal grades (%)

K = Length of vertical curve per percent change in A, known as the design control.

a. Crest Vertical Curve

The minimum length of crest vertical curve is established based on sight distance. For most cases SSD controls. Select the appropriate K value as per Table 3-34.

b. Sag Vertical Curve

The minimum length of sag vertical curve is established based on headlight sight distance. Select appropriate K value as per Table 3-36. Additionally, check to ensure that the minimum length satisfies requirement for riding comfort as follows:

$$L = \frac{AV^2}{46.5}$$

Where: L = Length of sag vertical curve (feet)

A = Algebraic difference in longitudinal grades (%)

V = Design speed (MPH)

2. There is a level point on a vertical curve, which may affect drainage of the roadway. Typically, the drainage of a roadway is not compromised if the vertical curve is sharp enough such that a minimum grade of 0.30% is reached at a point approximately 50 feet from the highpoint (for crest vertical curve) or low point (for sag vertical). This corresponds to a K value of 167 feet per percent change in grade, which is represented as “drainage maximum” line in Figures 3-43 (for crest vertical curve) and 3-44 (for sag vertical curve). All combinations above or to the left of this line satisfy the drainage criterion. The combinations below and to the right of “drainage maximum” line include flatter vertical curves. If so, then it is necessary to ensure that proper drainage of the roadway is provided. It is not intended that these values be considered a design maximum. The maximum algebraic difference in tangent grades (A) that an angle point is permitted for various design speeds is shown in the following table. This table is based on a length of vertical curve equal to 3 times the design speed (in MPH).

Use of a Profile Angle Point	
Design Speed (MPH)	**Maximum A (percent)**
25	0.70
30	0.55
35	0.50
40-45	0.40
50	0.35
55-60	0.30

2.1.4 CROSS SECTION ELEMENTS

2.1.4.1 CROSS SLOPE

A. In tangent portion of the roadway having up to two traveled lanes in same direction of travel, the cross slope of the traveled lane(s) shall be 2%. In areas of horizontal curvature, adjust cross slope as per requirements in Paragraphs 2.3.3 B. and 2.3.3 C. For roadways having three or more traveled lanes in the same direction of travel, adjust the cross slope such that the cross slope to the left of the middle lane is reduced to 1.5% and the cross slope to the right of the middle lane is increased to 2.5%.

B. The cross slope of the shoulder should be sufficient to remove water resulting from rain or snow. The maximum cross slope of the shoulder shall not exceed 8%.

C. Following are recommended cross slopes for various types of shoulders:

1. 2 to 6% for bituminous or concrete-surface shoulder (often the cross slope is equal to the adjacent traveled way).
2. 8% for vegetated shoulder.

2.1.4.2 WIDTH OF LANE

Lane width shall be 12 feet. For low-speed urban streets, 11-feet lanes are acceptable. In areas of curvature, it may be necessary to increase the width of lane as per Paragraph 2.1.3.3 F.

2.1.4.3 WIDTH OF SHOULDER

A. A shoulder is the portion of the roadway contiguous with the traveled way. It is provided to accommodate stopped vehicles and for emergency purposes. The shoulder is also often used to contain and remove water resulting from rain or snow. An additional benefit that results from providing a shoulder is increased sight distance in areas of curvature as well as giving drivers a sense of safe and open roadway.

B. Width of shoulders vary by roadway classifications and generally vary from 6 to 8 feet. Heavily traveled, high-speed highways, and highways carrying large numbers of trucks should have usable shoulders at least 10-feet wide and 12-feet wide where truck volume is more than 250-average daily traffic.

C. Provide a shoulder having a minimum width of 3 feet on both sides of the traveled way. For additional discussion on shoulders see Chapter 4 of the Green Book.

2.1.4.4 ROLLOVER

Rollover is defined as the algebraic difference (in percent) in cross slope between two adjacent traveled lanes or between the traveled lane and shoulder. Do not exceed the following values:

A. Between two adjacent traveled lanes: 4% maximum.

B. Between traveled lane and shoulder: 8% maximum.

2.1.4.5 SIDEWALK AND PEDESTRIAN ELEMENTS

A. Sidewalks and accessibility ramps shall comply with the requirements of the Americans with Disabilities Act (ADA) Accessibility Guidelines. Location of sidewalks and accessibility ramps are to be developed in conjunction with the Architectural and Traffic Engineering Disciplines, and reviewed by the Law Department.

B. The minimum clear width of the sidewalk shall be 5 feet. Additional width may be required to accommodate signs, structures, traffic signal control devices, etc.

C. The maximum sidewalk cross slope is 2%.

D. For accessibility ramp requirements refer to Standard Detail 062.021.

E. Do not locate utility hardware such as covers, grates, and obstructions within any accessibility ramp, including the landing.

2.1.4.6 CURBS

A. General

1. Do not use curbs for the purpose of redirecting errant vehicles away from roadside obstructions. Use an appropriate traffic barrier where such redirection is necessary.
2. Curbs are primarily used on frontage and low-speed roadways to facilitate drainage of the roadway, to separate vehicular traffic and pedestrians, roadside maintenance operation, and to delineate the edge of roadway. Curbs should not be used adjacent to high-speed traveled lanes or ramp areas except at the outer edge of the shoulder where needed for drainage.

3. Curbs shall not be placed at roadside barriers such as end terminals or impact attenuators. If necessary for purpose of continuity, curbs should be depressed to a 2-inch maximum height. Where it is not possible to achieve a 2-inch maximum height and a curb is required for purpose of continuity use a sloping curb placed for 50 feet in advance of the roadside barrier and along its entire length, including flared portions.
4. When curbs are to be used in conjunction with guiderails, consult the Traffic Engineering discipline for curb type.

B. Curb Configurations

1. Sloping Curb

   The design of the sloping curb allows for vehicles to easily mount the curb. Sloping type curbs are required when the 85th percentile speed is 45 MPH or greater. For Sloping Curb (Type II), refer to Standard Detail 060.003.

2. Vertical Curb

   Vertical curbs are intended to discourage vehicles from leaving the roadway. When proposed, vertical curbs are desirable in conjunction with safety or inspection walks along the faces of long walls, bridges, and tunnels. For Vertical Curb (Type I), refer to Standard Detail 060.003. Limit curb reveal to the following:

   a. 6-inch maximum for 85th percentile speed below 45 MPH and where sidewalks are proposed and frequent pedestrian activity is expected.
   b. 4-inch maximum for 85th percentile speed greater than 45 MPH and where infrequent pedestrian activity is expected.

C. Curbs in Along Bridge Parapets and Retaining Walls

1. The vertical curb should match the vertical curb use on the approach roadways.

2.1.4.7 SIDE SLOPES

Side Slopes (foreslope and backslope) are the immediate areas adjacent to the traveled way or shoulder and should be designed in accordance with the AASHTO's Roadside Design Guide. When required, design side slope as follows:

A. Desirable side slope: 1V (vertical):4H (horizontal) or flatter

B. Side slope of 1V:3H or steeper is permitted when site conditions preclude use of desirable foreslope. However, if used, coordinate with the Traffic Engineering Discipline for roadside design requirements.

C. A side slope of 1V:2H cannot be mowed mowers. For stability concerns regarding slopes, consult Geotechnical Engineering. For roadside design requirements, consult with the Traffic Engineering Discipline.

2.2 Elements of Design for Container Terminals and Intermodal Container Transfer Yards

2.2.1 Grading

A. Grading shall be compatible with the equipment to be used for handling and stacking containers, layout, and to provide for drainage of the area. The equipment could include straddle carriers, reach stackers, top picks, rubber tire gantry (RTG) cranes, rail mounted gantry cranes, tractor trailers, and bomb carts or yard hostlers (custom chassis and tractor combination). See Figure 1 and Figure 2 for typical grading patterns.

B. The grade in areas designated for stacking or storage of containers shall not exceed 2%. Desirable grade is 1% to 1.5%. Additionally, avoid abrupt changes in grade. This is especially critical when the equipment includes straddle carriers.

C. The grade in areas not designated for stacking or storage of containers shall be compatible with the equipment to be used within those areas. However, grade should not exceed 4%.

D. The grade in an area designated for a RTG operation requires special attention. Generally, is it required that the RTG be level in the gantry direction. This is achieved by establishing identical grades at both sides of the RTG gauge or gantry. However, some slope in the gantry direction may be acceptable. If necessary, consult with the manufacturer of the RTG crane to determine maximum permissible slope in the gantry direction.

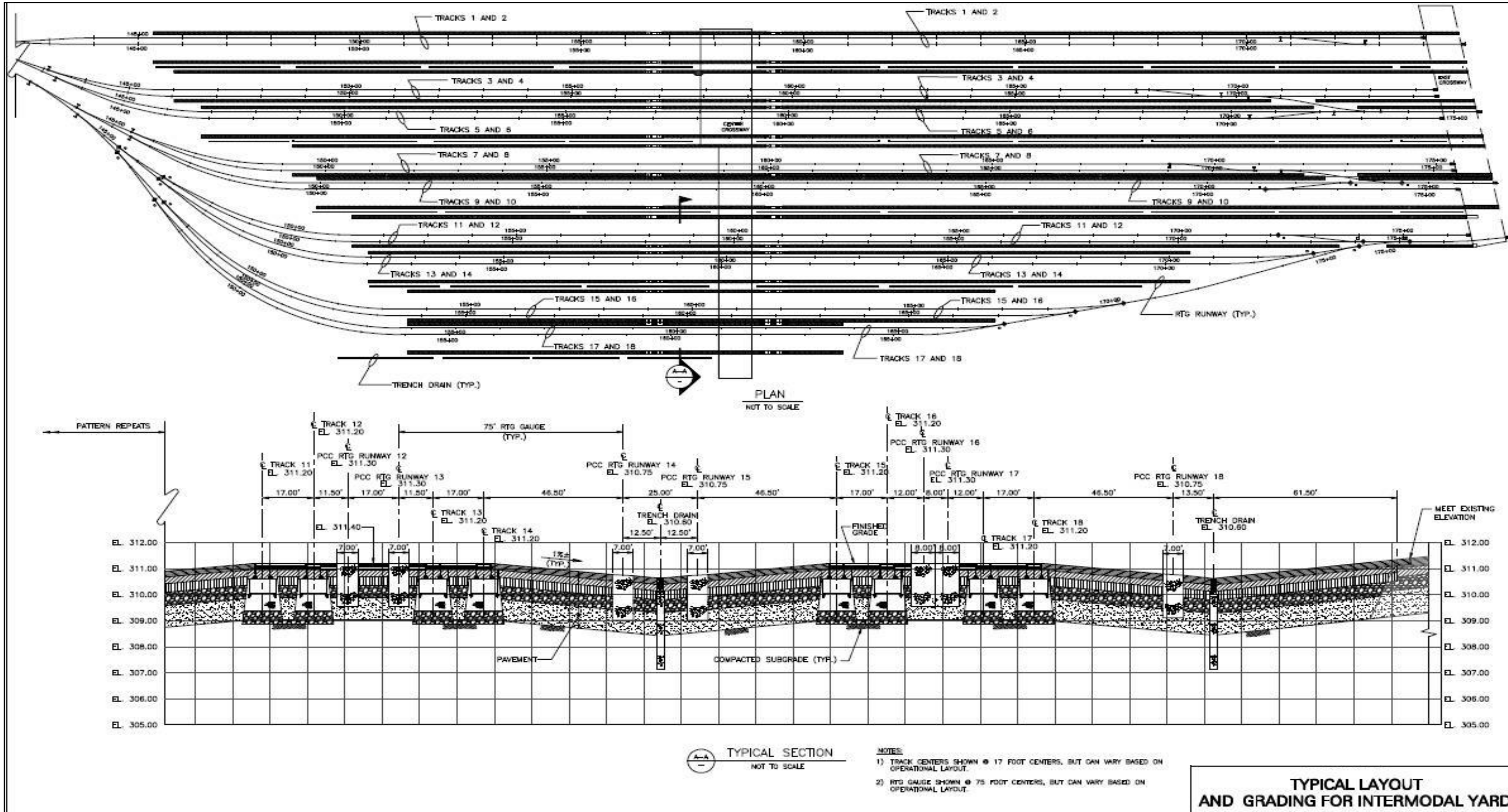

Figure 1
Typical Layout and Grading for Intermodal Yard

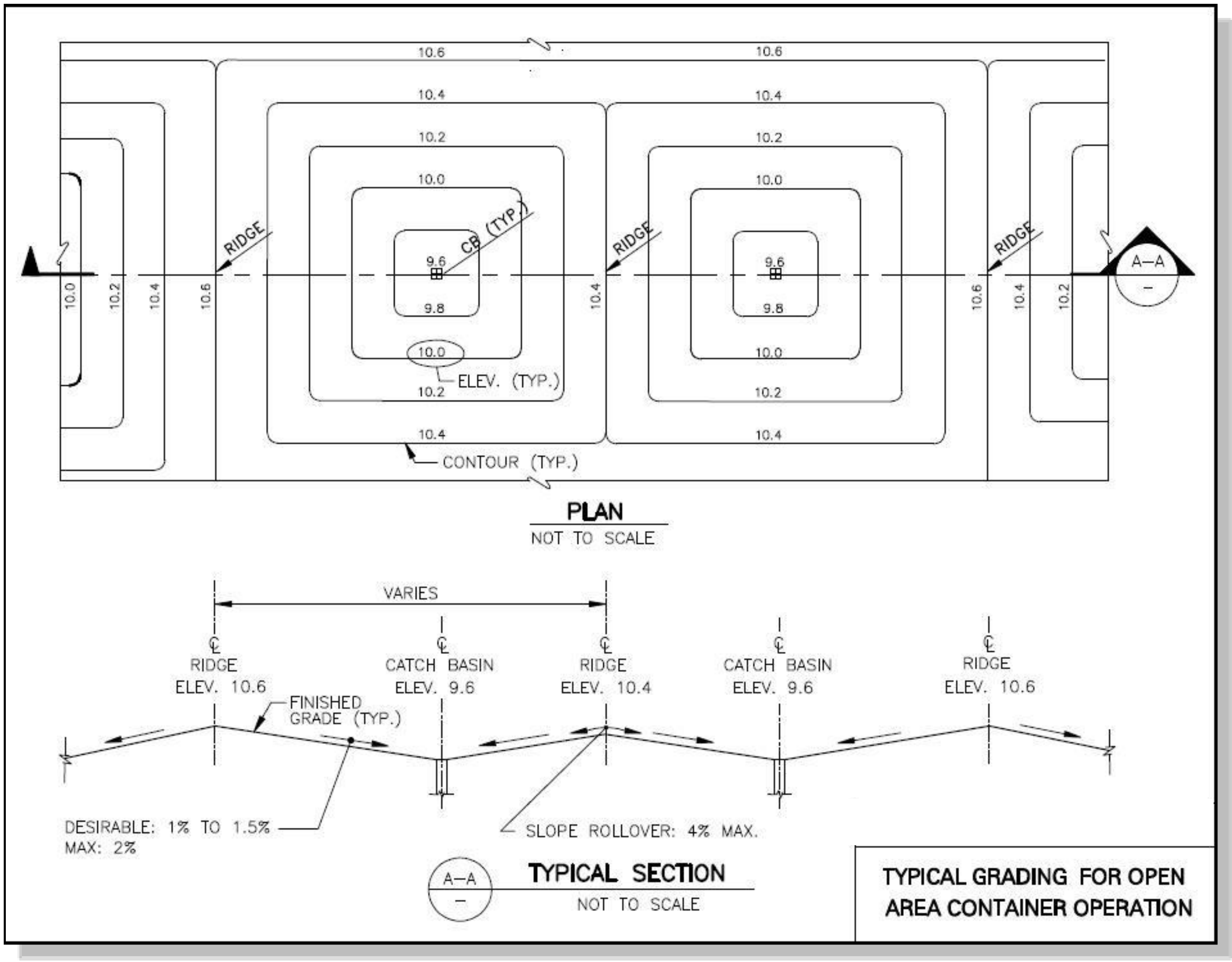

Figure 2
Typical Grading for Open Area Container Operation

E. Establish ridges and low points to comply with the requirements of Paragraph 2.6.4.B. or Catchment Layout under Elements of Design for Stormwater Drainage System. See Figure 2 for typical grading pattern where catch basins are used. In areas designated for stacking or storage of containers, limit slope rollover (at ridges and low points) to absolute maximum of 4%.

2.2.2 DRAINAGE

A. Use catch basins, trench drains, or combination thereof compatible with the grading to collect runoff.

B. In the case of catch basins proposed in open areas, comply with the requirements of Paragraph 2.6.4.B. or Catchment Layout under Elements of Design for Stormwater Drainage System.

2.2.3 SHIP CRANE RAILS

A. Historically, the gauge (centerline to centerline) for ship crane rails is 50 feet. However, with the introduction of larger ships or vessels the gauge is now commonly 100 feet. The Line Department will establish the gauge. Additionally, the requirement for equal leg or unequal leg cranes must be established. In the case of an equal leg crane, the elevation of both the water and landside crane rails are equal. In the case of an unequal leg crane, the elevation of the waterside crane rail is slightly higher than the landside crane rail. Use of unequal leg cranes is common to ensure to allow for proper drainage or run-off of the wharf and the immediate adjacent upland area.

B. Crane rails shall have 0% longitudinal grade unless otherwise directed in writing by the tenant and/or Line Department.

C. Catch basins and their associated (“waffle”) grading shall not be located between the rails and shall be as far as practical from the rails unless otherwise specified by the Line Department. Typically, there is a slope from a crown (ridge) toward the waterside rail, and drainage flows across that rail and spills over the face of the wharf (in lieu of using catch basins).

D. The typical section for equal leg crane rails has a crown between the rails. For unequal legs, the crown may be at or landward of, the landside rail if minimum slope requirements can be achieved.

2.2.4 TRACK CENTERS AND CLEARANCES

A. Absolute minimum track centers for intermodal yards shall be 14’-0”. Greater spacing maybe required to allow for serviceability of the rail cars.

2.2.5 GRADING AT TRUCK DOCKS AND BUILDINGS

A. Grades shall be coordinated with the proposed building floor elevation. Establish grades at truck docks based on the Line Department written requirements for height, load levelers, etc.

B. It is desirable to slope the grade away from the truck docks and the buildings. Depressed truck docks require drainage. Use trench drains for drainage and ensure that maintenance cleaning can be performed.

C. The desirable maximum slope for depressed truck docks is 3% with an absolute maximum slope of 10%.

2.3 Elements of Design for Airfields

2.3.1 Classification and Geometry

A. In accordance with Federal Aviation Administration (FAA) classification policy for airports, the airports operated by the PANYNJ fall under Aircraft Approach Categories (AAC) C and D. Elements of design shall comply with all requirements of the Airplane Design Group (ADG) noted herein.

	Aircraft Approach Category (AAC) C and D (Distance in Feet)				
	JFK	EWR	LGA	SWF	TEB
Airplane Design Group (ADG)	VI	V	IV	V	III
Runway Safety Area (RSA) (total width from centerline of R/W)	500 250	500 250	500 250	500 250	500 250
Taxiway Object Free Area (TOFA) (total width from centerline of T/W)	386 193	320 160	259 129.5	320 160	186 93
Taxiway Safety Area (TSA) (total width from centerline of T/W)	262 131	214 107	171 85.5	214 107	118 59
Taxilane Object Free Area (total width from centerline of taxilane)	334 167	276 138	225 112.5	276 138	162 81

FAA AC 150/5300-13A - Change 1, Table 3-5 and Table 4-1

B. Design all runway elements to meet applicable requirements of FAA Advisory Circular (AC) entitled "Airport Design" 150/5300-13A; Change 1 (hereafter AC).

C. For taxiways, the PANYNJ Aviation Planning Division will establish the Taxiway Design Group (TDG). Based on the selected TDG, design all taxiway elements to meet applicable requirements of the AC.

D. Layout and geometry of the airfield (runways, taxiways, restricted vehicle service road, etc.) shall conform to the approved Airport Layout Plan and/or approved functional drawings. Note: Required separations may not always comply with airport geometry requirements as set forth in the AC in which case the airport operates under a Modification of Standards.

E. Markings for Runway Holding Position.

Markings for Runway Holding Position					
	EWR	JFK	LGA	SWF	TEB
Minimum Distance from R/W Centerline to Hold Side of Marking	280 feet	280 feet	250 feet	280 feet	250 feet

2.3.2 Surface Gradient

A. Longitudinal grade and cross slope shall conform to requirements in the AC.

B. Projects requiring maintenance of runway or taxiway pavements (overlays, inlays, etc.) may require adjustment to elements of design noted herein. Evaluate existing grades (longitudinal and cross slope) to determine if conditions would not allow for compliance with the AC. If existing conditions do not allow for compliance with the AC, then a design exception must be obtained from the Chief Civil Engineer.

C. Longitudinal Grade

1. Generally, as flat as possible, using the minimum grades consistent with surrounding controls (i.e. intersections, adjoining and connecting T/W, R/W, and aprons, etc.).
2. For Runway (R/W), the maximum longitudinal grade is ±1.5% however; longitudinal grade may not exceed ±0.80% in the first and last quarter, or first and last 2,500 feet, whichever is less, of the R/W length. The maximum allowable grade change is ±1.5%; however, no grade changes are allowed in the first and last quarter, or first and last 2,500 feet, whichever is less, of the R/W length. Vertical curves for longitudinal grade changes are parabolic. The length of the vertical curve is a minimum of 1,000 feet for each 1.0% of change. The minimum allowable distance between the points of intersection of vertical curves is 1,000 feet multiplied by the sum of the grade changes (in percent) associated with the two vertical curves. Refer to Figure 3-22 of the AC.
3. For Taxiway (T/W), the maximum longitudinal grade is ±1.5% with vertical curves having a minimum length of 100 feet for each 1.0% change in grade. The maximum algebraic change in longitudinal grade is 3.0%. The minimum distance between changes in grade shall be 100 feet times the algebraic sum of the grade changes in percent. A vertical curve is not necessary when the grade change is less than 0.40%, nor where a T/W crosses a R/W or T/W crown. Primary, higher speed T/W should be designed to higher criteria than less-used T/W whose geometry dictates slow speeds.
4. The surface gradient requirements for the primary or higher category R/W take precedence over the lower category R/W. Transverse grades may have to be adjusted to avoid excessive R/W roughness. The centerline profiles of both runways take precedence over the offset (wheel path) profiles and cross slopes.

2.3.3 CROSS-SLOPE

2.3.3.1 GENERAL

A. For R/W, refer to Figure 3-23 and Table 3-3 of the AC. For T/W, refer to Figure 4-33 and Table 3-3 of the AC.

B. Both R/W and T/W are normally designed as crowned sections at 1.5% cross slopes. The minimum cross slope is 1.0%. The absolute minimum cross slope is 0.5% for short distances on non-primary surfaces (except at intersections).

C. R/W cross slope is not changed to accommodate taxiways.

D. For a T/W with a one-way cross slope, limit the cross slope to 1.0% desirable maximum. Steeper slopes can tilt aircraft causing fuel transfer within the wings and passenger discomfort. Where a slope greater than 1.0% (1.5% maximum) is required on the low side of the centerline, reduce the high side in order to result in a net effective slope of 1.0% between the main gear assemblies.

E. For shoulder and erosion pavement surfaces, the cross-slope shall be 1.5% to 5.0% (for the R/W or T/W, the typical grades are 3.0%).

F. For unpaved surface adjacent to pave surface (i.e. turf area), the cross slope shall be 1.5% to 3.0%. Per the AC, along the edge of pavement, ensure that the design complies with the requirement of having a 1.5-inch drop to the top of the unpaved turf surface and for a cross slope of 5.0% for a minimum of 10 feet width; this promotes drainage away from the shoulder/erosion pavement.

2.3.3.2 ADJUSTMENT TO GRADES AT INTERSECTIONS

A. In the case where a R/W and T/W intersect, maintain the longitudinal grade of the R/W through the intersection. Maintain the R/W cross slope, usually 1.5%, to the edge of runway. Adjust the grades of the intersecting T/W to meet the edge of runway.

B. In the case where two taxiways intersect, maintain the longitudinal grade and cross slope of the primary taxiway through the intersection. At a minimum, maintain the primary T/W cross slope within the width of the keel or path of the main gear assemblies. Adjust the grades of the intersecting T/W to meet the edge of the keel or path of the main gear assemblies of the primary T/W.

C. In the case where two runways intersect, apply the following:

1. The primary R/W takes precedence over the secondary R/W. The centerline profiles of both runways take precedence over the offset (wheel path) profiles and cross slopes. The design of the more important element produces fixed grades for succeeding elements.
2. Grade to maintain longitudinal grade requirements for both R/W centerlines. This generally results in very flat cross slopes within the intersection. In order to promote the best possible drainage, the change in cross slope (or runout) to the standard cross slope (1.5%) should be made as rapidly as possible up to a maximum rate of 0.25% in 25 feet.
3. Maintain a smooth profile within the width of the keel or the path of the main gear using vertical curves. It is acceptable to use an approximate, non-mathematical curve produced by increasing (decreasing at sags) the slope between successive spot elevations with a rate of change equal or greater than the prior rate of change. Note: R/W intersection grading is an iterative process. This is because of practical considerations of presentation and field layout (station spacing, rounding off, etc.) and paving tolerances in the field (operator controls, rolling, and finishing, etc.).
4. Verify the proposed R/W profile using Aircraft Simulation Software. Use the B-737-800 aircraft to run the simulation tests. Run simulations for take-offs, landings, and velocity sweep. Vertical accelerations should be as low as practical, but should not exceed 0.3g at the center of gravity.

2.3.3.3 CHANGE IN CROSS SLOPE

A. Runway: Change in cross slope is not desirable. Where required, use smallest rate of change practical up to a maximum of 0.25% in 25 feet.

B. Taxiway: Keep to minimum consistent with aircraft speed up to desirable maximum rate of change of 0.25% in 25 feet. The absolute maximum of 0.50% in 25 feet may be used on very slow speed taxiways, and only where surroundings dictate the need. Transitions from positive to negative cross slopes are discouraged. When necessary, the rate of cross slope change from +0.5% to –0.5% should be accomplished as rapidly as possible to avoid creating drainage problems.

2.3.4 APRON GRADING

A. Maximum allowable grade in any direction is 1.0%. The maximum grade change is 2.0%. The minimum grade in any direction is 0.5% for rigid pavements and 0.75% for hot-mix asphalt pavements. Design apron grades to direct runoff of storm water away from any building.

B. Conform to National Fire Protection Association (NFPA) requirements for location, spacing, and grading to drainage inlets in aircraft fueling areas.

2.3.5 STABILIZATION REQUIREMENT FOR AREAS SUBJECT TO JET BLAST

Ensure areas that will be subject to jet blast are properly stabilized with a pavement. The areas to be stabilized will be provided the PANYNJ Aviation Planning Division. The pavement shall conform to the latest PANYNJ standard detail entitled Flexible Pavement Sections-LGA (062.001) or Flexible Pavement Sections-JFK/EWR (062.004), or with the latest AC, whichever results in thicker pavement.

Subject to concurrence by the Facility, an artificial turf system can be utilized for the areas adjacent to certain airfield pavements as an alternate to natural turf to mitigate localized erosion problems caused by jet blast. For additional discussion on airside application of the artificial turf, refer to AC 150/5370-15B.

2.4 Elements of Design for Track Work

2.4.1 Port Authority Trans-Hudson (PATH) Facilities

2.4.1.1 General

PATH track utilized for revenue service generally shall conform to Federal Railroad Administration (FRA) standards for Class 3 track and where possible designed for an operating speed of 60 MPH. There are intermittent lengths of certain revenue tracks within the tunnels that conform to FRA Class 2 standards and are designed for an operating speed of 30 mph. Refer to the most current copy of the PATH Book of Rules (2) for those locations. PATH track utilized for non-revenue service (or yard tracks) shall conform to standards for FRA Class 1 track and designed for an operating speed of 15 MPH.

The New Jersey Administrative Code Section 7:13-11.6 requires that the travel surface of a railroad be constructed at least one foot above the BFE, unless it is not feasible and the railroad is constructed as close to the BFE plus one-foot elevation as possible. Refer to Design Guidelines - Climate Resilience for BFE information.

In addition to all criteria herein, all design must comply with the most current version of the PATH Track Standards Manual (3).

2.4.1.2 Gage

A. PATH track shall be of standard 4' - 8½" gage. The gage shall never be less than 4' - 8" regardless of the class of track. Gage widening as required shall be applied to all curves having a radius of 750 feet or less. See table below.

B. The standard gages measured perpendicular to the track (radially on curves) between opposite points on the gage surface of the rails, in a plane 5/8 inch below the rail head, shall be in accordance with the following table:

Track Description	PATH Standard Gage
Tangent	4' - 8½"
Curve having a radius greater than 750 feet	4' - 8½"
Curve having a radius between 750 and 350 feet	4' - 8¾"
Curve having a radius less than 350 feet	4' - 9"

2.4.1.3 Horizontal Alignment

All of the tunnels in the PATH system were constructed by the Hudson and Manhattan Railroad Company (H&M) well before any of the present design criteria were established. The alignment of the tracks in these tunnels is generally not able to be modified without detrimental effect on clearances. Any proposed modification to track geometry must be thoroughly analyzed and vetted by using the original H&M tunnel books and drawings as a guide.

In general, the track should remain in the location and configuration in which it presently exists.

A. General

1. Horizontal track alignment consists of a series of straight (tangent) lengths of track connected by simple, compound, transition, or reverse curves.

2. The outer or high rail on curves and the rail farthest from the contact rail on tangents shall be used as the line rail. The line rail shall be used whenever any work involving the horizontal alignment is performed. Reference all horizontal alignment measurements and sightings to the gage line of the line rail.

3. The minimum distance between centers of tangent tracks at the same level shall be as follows:

   a. 13 feet in subways with no interior walls or columns.

   b. 13 feet outside of subway.

   c. On curves, to provide clearance between cars equivalent to that obtained for tangent track above, increase the minimum track center distance to compensate for end and center excesses of rail cars and the effects of superelevation.

B. Minimum Length of Tangent

1. Except as noted below, determine the desired minimum length of tangent for revenue track by the following formula:

$$\mathrm{LT} = 3\mathrm{V}$$

Where: LT = Minimum length of tangent (feet)

V = Design speed (MPH)

Required Tangent Length	Mainline Track		Yard Track	
Between Reverse Curves	Standard	100 feet	Standard	--
	Desired Minimum	3V	Desired Minimum	85 feet
	Absolute Minimum	50 feet	Absolute Minimum	40 feet
Preceding a Point of Switch (PS)	Standard	100 feet	Standard	--
	Desired Minimum	3V	Desired Minimum	--
	Absolute Minimum	40 feet	Absolute Minimum	40 feet
Between Facing Points of Switch	Standard	3V	Standard	--
	Desired Minimum	60 feet	Desired Minimum	60 feet
	Absolute Minimum	40 feet	Absolute Minimum	33 feet
At the Ends of Platforms	Standard	50 feet	Standard	--
	Desired Minimum	15 feet	Desired Minimum	--
	Absolute Minimum	SEE NOTE	Absolute Minimum	--

NOTE: Calculate the absolute minimum to ensure that, while the curve may encroach into the platform limits, the rail vehicle's body may neither fall outside the limits of ADA requirements nor comes closer than 1-inch to the face of platform

C. Horizontal Curves

1. Define horizontal curves by either radius (preferred) or by the chord definition of curvature and specify by degree of curve (D):

$$D = 2sin^{-1}(\frac{50}{R}) \quad \text{or} \quad R = \frac{50}{\sin\ (0.5D)}$$

Where: D = Degree of curvature (degrees)

R = Radius of curve (feet)

In reconstructing existing tracks, every opportunity shall be taken to lessen the existing curvature.

2. Determine the minimum length of horizontal curve by the formula below, except that a desired minimum circular curve length of 100 feet (excluding spirals) and an absolute minimum circular curve length of 50 feet (excluding spirals) shall be maintained regardless of speed:

$$L_c = 3V$$

Where: L_c = Minimum length of horizontal curve excluding spirals (feet)

V = Design speed (MPH)

3. Minimum Radius

   a. For mainline running track, the absolute minimum radius of circular curves is 115 feet.

   b. For mainline running track, the minimum desired radius of circular curves is 750 feet.

   c. For yard track, the minimum desired radius of circular curves is 320 feet.

D. Spiral Transition Curves

1. Spiral transition curves are curves of gradually increasing curvature providing smooth transition of train cars from tangent to circular track. Spiral transition curves are not required at turnouts and crossovers. In general, the spiral transition curve shall be of sufficient length to permit full superelevation runoff within its length.

2. Spiral transition curves in mainline track shall be placed at the ends of simple curves and between segments of compound curves.

3. Use the spiral as found in the American Railway Engineering and Maintenance-of-Way Association's (AREMA) Manual for Railway Engineering, Chapter 5.

4. Minimum length of spiral transition curves shall be the greatest length obtained from the formulas below. In no case shall a spiral transition curve with a length less than 40 feet be used. It is desirable that a minimum length of 100 feet be used on all mainline track.

$$L_s = 62E_a$$

$L_s = 1.63E_uV$ (desired minimum)

$L_s = 1.22\,E_uV$ (absolute minimum, if L_s=$1.63E_uV$ is cost prohibitive or due to space restrictions)

Where: L_s = Length of spiral transition curve (feet)

E_a = Actual track superelevation (inches)

E_u = Unbalanced superelevation (inches)

V = Design speed (MPH)

E. Reverse Curves

Avoid reverse curves on mainline track. If necessary, then approval from PATH is required. The reverse curve shall have spirals or transition curves with a minimum tangent distance of 100 feet between reverse curves and with the rate of change of superelevation being constant through both curves.

F. Compound Curves

Compound circular curves may be used provided that they are connected by an adequate spiral or transition curve. Spiral or transition curve for compound curves are not required when the difference in radii is less than the following:

$$R_l - R_s < 0.34({}^{R_s}/_{V})^2$$

Use the formulas in Paragraph 2.4.1.3.D. to calculate the length of compound spiral ($\mathrm{L_{cs}}$) when

$$R_l - R_s > 0.34({}^{R_s}/_{V})^2$$

Where: $\mathrm{E_a} = \mathrm{E_{al}} - \mathrm{E_{as}}$ and $\mathrm{E_u} = \mathrm{E_{ul}} - \mathrm{E_{us}}$

R_l = Larger radius (feet)

R_s = Smaller radius (feet)

V = Design speed (MPH)

$\mathrm{E_a}$ = Actual track superelevation (inches)

$\mathrm{E_u}$ = Unbalanced superelevation (inches)

$\mathrm{E_{al}}$ = Actual track superelevation of larger radius (inches)

$\mathrm{E_{as}}$ = Actual track superelevation of smaller radius (inches)

$\mathrm{E_{ul}}$ = Unbalanced track superelevation of larger radius (inches)

$\mathrm{E_{us}}$ = Unbalanced track superelevation of smaller radius (inches)

It is desirable that each curve segment in a compound curve shall be at least 100 feet in length, excluding spirals. However, maintain a minimum of length 50 feet at all times.

G. Horizontal Angle Points

Curves with a calculated external distance of ½ inch (0.0417 feet) or less are too inconsequential to construct in the field and maintain. Avoid such horizontal curves by either lengthening the curve or by using a horizontal angle point when the algebraic difference of the bearings is 0.15° (0° 09') or less.

2.4.1.4 TRACK SUPERELEVATION

A. General

Superelevation is the amount that the outer rail of a curve is raised above the inner rail. It is provided to overcome or partially overcome the effects of curvature and speed. Balanced superelevation is that which exactly overcomes the effect of negotiating a curve at a given speed for a given radius of curvature, placing the resultant of the centrifugal force and the weight of the equipment perpendicular to the plane of the track. Unbalanced superelevation is that amount greater or less than the balanced superelevation requirements for a given combination of speed and curvature.

B. Actual Superelevation

All curves shall have a minimum of ½ inch of superelevation, but shall not exceed 4 inches of actual superelevation.

C. Unbalanced Superelevation

Unbalanced superelevation may be used on curves where physical conditions, such as certain tunnel areas, restrict the application of actual superelevation. The amount of unbalanced superelevation shall be limited to 1 ½ inch if practical, but shall not exceed 3 inches. Trackwork at the World Trade Center has been approved for and designed using a maximum of 4 inches unbalanced superelevation.

D. Constant Superelevation

Superelevation shall be constant throughout horizontal curves. Accomplish superelevation by maintaining the top of inside rail at the top of rail profile and raising the outside rail by an amount equal to the track superelevation. If a curve is superelevated, the full superelevation should be provided throughout the curve.

E. Track Superelevation

1. Determine track superelevation to the nearest ¼ inch by the following formula:

$$E_q = E_a + E_u = 0.0007DV^2 = 4.01\left({V^2}/{R}\right)$$

Where: E_q = Equilibrium superelevation (inches)

E_a = Actual track superelevation (inches)

E_U = Unbalanced superelevation (inches)

D = Degree of curvature (degrees)

V = Design speed (MPH)

R = Radius of curve (feet)

2. Determine track unbalanced elevation by the following formula:

$$Eu = 0.000292V^2D \text{ or } Eu = 1.67\left({V^2}/{R}\right)$$

These formulas result in a theoretical split of the total elevation to 60% actual superelevation and 40% unbalanced elevation. The unbalanced elevation may be increased above this limit to the maximums stated above only where required by design speeds due to constrictions of the alignment.

F. Superelevation Runoff

1. Superelevation runoff must occur at a uniform rate within the full length of the spiral transition curve. If physical conditions do not permit a spiral transition curve long enough to accommodate the minimum length of superelevation runoff, then up to 1 inch of the superelevation runoff may be made on tangent track if approved by PATH.

2. The maximum rate of curve runoff shall be as follows:

Authorized Speed (MPH)	Rate of Runoff (in 31 feet)
30 and less	¾ inch
31 to 45	⅝ inch
46 to 60	½ inch

3. Portions of the PATH track network are built with a superelevation runoff rate of one inch in 31 feet. Review PATH Track Charts [(4)] to determine the applicable superelevation runoff rate.

G. Superelevation

Superelevation of turnouts and crossovers is not permitted, except with approval of PATH.

2.4.1.5 VERTICAL ALIGNMENT

A. General

1. Join constant top of rail profile grades with vertical curves at crest and sags. On horizontal curves, top of rail profile shall be along the low rail (rail on inside of curve).

B. Maximum Allowable Grades

1. Mainline Track shall not have grades exceeding 4.0%.
2. Yard track shall not have grades exceeding 1.0%.
3. Desirable grade within station shall be 0.0%, but up to 0.4% will be allowed.
4. The maximum allowable grade through turnouts and crossovers shall be 1.5%, though a flatter grade is desired.

C. Minimum Length of Constant Profile Grade

1. Avoid frequent changes in profile grade.
2. Generally, determine the minimum length of constant profile grade by the formula below, except that a desired minimum constant profile grade of 300 feet shall be maintained.

$$LVT = 3V$$

Where: LVT = Minimum length of constant vertical tangent (feet)

V = Design speed (MPH)

3. If the desired minimum vertical tangent length of 300 feet cannot be achieved, an absolute minimum of 100 feet must be maintained.

D. Vertical Curves

1. Minimum Length of Vertical Curve

   a. The minimum length of vertical curve is 100 feet or greater based on the length as calculated using the following formulas:

$$LVC = (G/g)\,x100$$

$$LVC = 3V$$

$$LVC = 2.15GV\left(\frac{V}{A}\right) = 2.15G({V^2}/{A})$$

Where: LVC = Length of vertical curve (feet)

G = The algebraic difference in profile grades approaching and leaving the vertical curve (%)

V = Train velocity (MPH)

A = Vertical acceleration, 0.6.

g = The rate of change of profile grade per 100-feet station, in percent, according to the formulas below.

   b. Determine the maximum rate of change of profile grade per 100-feet station (g), in percent, as follows:

$g = \frac{3000}{V^2}$ (at crest vertical curve on tangent)

$g = \frac{4500}{V^2}$ (at sag vertical curve on tangent)

Where: V = Design speed (MPH)

   c. Maintain an absolute maximum rate of change of profile grade of 0.83% per 100-feet station.

   d. The minimum radius of vertical curve shall be 2,000 feet. Radius of vertical curve is defined by:

$$RVC = \frac{100\ LVC}{G}$$

2. Avoid areas of combined vertical and horizontal curves.
3. Vertical curves within the limits of spirals are not permitted.
4. Compound vertical curves are not permitted.
5. Vertical curves within platforms, or within 50 feet of a platform end, are not permitted.

E. Reverse Vertical Curves

Provide a minimum vertical tangent of 100 feet between reverse vertical curves.

F. Vertical Angle Points

Curves with a calculated middle ordinate less than 1/4 inch (0.021 feet) are too inconsequential to construct in the field and maintain. Avoid such vertical curves by either lengthening the curve or by using a vertical angle point when the algebraic difference of the profile grades is 0.16% or less.

2.4.1.6 STATIONS

A. General

Tracks within station limits shall be tangent where practicable. The minimum platform length shall be 530 feet.

B. Platform Gaps

Provide minimum of 1inch gap between the vehicle and the platform edge.

The maximum gap shall be controlled by the most current version of the ADA Accessibility Guidelines.

2.4.1.7 CLEARANCES AND TRACK CENTERS

A. The minimum desirable wayside clearance along PATH Right-of-Way, west of the Tunnel Portals is 8'- 6", measured from centerline of track, except as noted below:

Station platforms	4' - 7½"
Employee platforms	5' - 8"

B. The minimum desirable wayside clearance on tangent track in PATH Tunnel System is 6' - 0" measured from center line of track, except as noted below:

Station platforms	4' - 7½"
Duct bank	5' - 6"

C. On curved tunnel track, clearances shall be increased by ½ inch per degree of curve to allow for end and center car overhang.

D. The minimum desirable overhead clearance along PATH Right-of-Way, west of Portals, is 17' - 0".

E. The minimum desirable overhead clearance in the PATH Tunnel System is 12' - 6".

F. The minimum desirable track centers for mainline and yard tracks, west of Portals is 13' - 0".

2.4.1.8 BALLAST

A. Ballast material shall meet requirements of the AREMA Manual for Railway Engineering, Chapter 1, Part 2, Table 1-2-1.

B. Ballast cross-sections shall conform to the AREMA Standard Sections. Maintain cribs at a maximum of 1 inch below top of tie. Specify an additional 6 inches of shoulder ballast for curves over l degree (Radius = 5,730 feet) having continuous welded rail.

C. Ballast shall meet AREMA recommendations for gradation size "3" except in locations of limited clearance between bottom of ties and the top of invert, where size "4" shall be used with permission of PATH.

D. Provide 12 inches of ballast below the bottom of tie, with an absolute minimum of 8 inches and a maximum of 14 inches.

2.4.1.9 ROADBED OR SUB-BALLAST

Roadbed, or sub-ballast, shall be a minimum of 8-inch thick unless soil conditions warrant greater thickness. Roadbed or sub-ballast, shall conform to Dense Graded Aggregate Base Course (DGABC) as per PANYNJ

Technical Specification Section 321123 entitled "Aggregate Base Course". Subballast shall be sloped to drain.

2.4.1.10 TIES

A. Provide concrete ties for mainline open area track. Provide wood ties for mainline tunnel track and yard track.

B. Wood ties shall be treated oak or mixed hardwood meeting all requirements of AREMA and the latest version of the PATH Standard Technical Specifications.

C. Tunnel and yard wood ties shall be 6"x8"x8'-6". Contact rail wood ties shall be 6"x8"x9'-6". Ties supporting switch machines shall be 10"x8" by length shown on PATH Standard Details.

D. Concrete ties shall be the "PATH Standard Concrete Tie" as shown in the PATH Standard Details.

2.4.1.11 TIE SPACING

A. Maintain wood tie spacing (center to center) as follows:

Track Description	Nominal Spacing (inches)	No. of Ties per 39 foot of rail	Maximum Spacing (inches)
Main	21½	22	26
Tunnel	18	26	24
Yard	24	19	30

B. Concrete ties shall be spaced at 30" center to center.

C. Provide contact rail ties every fifth tie, with the exception of end approaches where they shall be placed as required. In no case shall the spacing between contact rail ties exceed 11 feet in main track, and 12.5 feet in yard track.

D. At rail joints, adjust spacing of ties such that maximum spacing (center to center) is 18 inches.

2.4.1.12 RAIL

A. Running Rail

Open area mainline track and yard tracks shall utilize 115 RE rail. Tunnel track shall utilize 100 ARA-B or 115 RE rail where clearance permits. All running rail shall be standard strength control cooled. Specify head hardened rail for all special trackwork, 100 feet beyond the ends and through the limits of all platforms, and 25 feet beyond and through the limits of curves of radius equal to or less than 750 feet.

B. Contact Rail

1. The contact rail is required to conduct electric current. Low electrical resistance is essential. On mainline track, the contact rail shall be 84C rail. Yard tracks shall utilize 150PS rail. Mainline tunnels shall utilize 75# HM section or 84C rail, based on available clearance.
2. Gage and height of contact rail above adjacent running rail shall be as shown on the PATH Standard details.

C. Check Rail (Restraining Rail)

1. Check rail shall utilize U69 section rail.
2. Horizontal curves having a radius less than 750 feet require a check rail. Place the check rail along the gage side of the inner or low rail on curves according to the following:
   a. Horizontal curve having a radius in the range of 750 to 350 feet – guard rail with flangeway opening of 2 inches.
   b. Horizontal curve having a radius of less than 350 feet - guard rail with flangeway opening of 2¼ inches.
3. Check rail shall extend a minimum of one rail length (39 feet) beyond the tangent point of curve on both sides.

D. Emergency Protection Rail

1. Emergency protection rail is required between the running rails in the following conditions:
   a. Provide two emergency protection rails on all tracks on bridges and open deck steel elevated structures.
   b. When the object being protected exists only on one side of the track, provide a single emergency protection rail adjacent to the running rail opposite the obstruction.
   c. On tracks on viaduct structures, or on embankments, to prevent trains from falling over the side of the structure, retaining walls or embankment. Show the emergency protection rail adjacent to the running rail opposite the edge of the structure, retaining wall or embankment where such edge is less than 6 feet from the gage side of the nearest running rail.
   d. At the approaching end of structures such as abutments, tunnel portals, or other particularly hazardous locations where a derailment could cause excessive damage to the equipment and the structures. Additionally, in tunnel locations to protect approaches to crash walls, columns, or other structural elements between adjacent tracks.
2. Provide emergency protection rails as follows:
   a. The guarding face of the emergency protection rail shall be at a distance of 10 inches from the gage of the nearest running rail.
   b. Scrap rail may be used for emergency protection rail provided the top of the emergency protection rail is equal to, or a maximum of 2 inches below, the top of the running rail.

E. Continuous Welded Rail (CWR)

CWR may be laid in fully ballasted track at those locations where the radius of the track equals or exceeds 700 feet and in installations of direct fixation track where the radius of the track is equal or greater than 500 feet. On curves with less than 700 feet radius for ballasted or 500 feet radius for direct fixation tracks, only bolted rail shall be installed. In guarded curves, only both running rails may be welded; guardrails shall be bolted.

CWR installations shall comply with the most recent edition of "PATH Procedures for Installation, Adjustment, Maintenance and Inspection of CWR" policy.

2.4.1.13 TRACK APPURTENANCES

A. Tie Plates and Rail Fasteners

1. In ballasted track construction, unless otherwise specified by PATH, rolled steel Pandrol plates are required.
2. In ballasted track construction, unless otherwise requested by PATH, Pandrol e2055 clips are required. In guarded curves, only the gauge side of the rail shall utilize a Pandrol e2055 clip, the field side (adjacent to the guard) shall utilize a Schwihag or PVT style clip unless otherwise specified.
3. In direct fixation construction or when using concrete ties, Pandrol Fastclips are required.

B. Spikes

Spikes may be either drive, screw, or lock types.

2.4.1.14 TURNOUTS AND CROSSOVERS

A. Geometry

1. In new construction, the following sizes of turnouts and crossovers shall be used where practicable:

   Mainline and tunnels (tangential type) Numbers 8, 9, 10, 11, 12, or 15

   Yards and leads (AREMA type) Numbers 6, 7, 8, 9, or 10

2. Certain tunnel turnouts are custom designed and smaller than specified above. These turnouts were designed as large as possible, based on available space. Refer to the most recent version of the PATH Track Charts for their size and locations.

B. Turnout and Crossover Components

1. All components of turnouts and crossovers shall comply with all requirements of the most recent version of PATH Standard Technical Specifications for Special Trackwork.
2. Gage and flangeway standards shall conform to the following table:

	Turnout Side			Main Side		
Frog #	Flange	Guard	Gage	Flange	Guard	Gage
3.5 and 4	2 ¼"	-	57”	-	-	-
5	2"	54¾"	56¾”	1¾”	54¾”	56½”
6 to 15	1¾"	56½"	-	-	-	-

Approaching special track work or curves, the rate of flangeway change shall be ¼ inch in 39 feet. Where restrictive alignment conditions exist, the rate of change may exceed the standard amount, but in no case may it exceed one-quarter inch in 31 feet for speeds over 30 MPH, or ¼ inch in 20 feet for speeds 30 MPH and below.

All switch points shall be installed with a ¼ inch rise above the stock rail. Graduated plate risers shall be used.

The throw of all switch points shall be measured opposite the first switch rod and shall be 3¾ inch.

3. Wood Timbers

   On all installations of turnouts using wooden ties, use 8"x10" timbers in the switch point areas, as shown on the PATH Standard Details; all others shall be 7 x9".

4. Frogs

   All mainline turnouts shall utilize solid cast manganese bolted frogs.

5. Guardrail

   Guardrails shall be placed opposite frogs, ahead of switches, and at other locations in special track work.

2.4.2 INTERMODAL CONTAINER TRANSFER YARDS AND FREIGHT TRACK

2.4.2.1 GENERAL

A. The PANYNJ owns several railroad yards used for the purpose of handling containers at our port facilities. These railroad yards are typically referred to as Intermodal Container Transfer (ICT) Yards. ICT yards include Express Rail – Staten Island, Express Rail – Elizabeth and Express Rail – Port Newark. Additionally, the PANYNJ owns and maintains a small network of railroad tracks used primarily for the movement of miscellaneous freight, passenger cars, and other commodities such as scrap metal. The Authority does not own, maintain, or operate any "mainline" railroad track used for the purpose of moving freight. Authority tracks are generally classified as either "yard" tracks or "industrial" tracks.

B. Various railroad companies utilize or operate the aforementioned facilities and networks and operate under the FRA Class 1 category or requirements.

C. In addition to the design elements that follow, the AREMA Manual for Railway Engineering shall supplement this manual. Particularly, Chapter 14, Yards and Terminals, in AREMA's Manual for Railway Engineering is an excellent source for fundamental design elements of intermodal yards.

D. Lastly, and in addition to review by PANYNJ staff, it is required that all projects requiring construction or modification of railroad tracks be reviewed by the operating railroads.

2.4.2.2 GAGE

The standard gage for track is to be measured between the running rails at right angles to the alignment of the track, 5/8 inch below the top of rail. Standard gage will be 4'-8½" on tangents, curves having less than 13 degrees of curvature, and through turnouts and crossovers.

2.4.2.3 HORIZONTAL CURVES

A. Degree of Curvature

   Curves should be designed and laid out using the chord definition of curvature.

$$D = 2sin^{-1}(\frac{50}{R}) \quad \text{or} \quad R = \frac{50}{sin\,(\frac{D}{2})}$$

Where: D = Degree of curvature (degrees)

R = Radius of curve (feet)

Absolute maximum degree of curvature shall be 10 degrees. If degree of curvature greater than 10 degrees is necessary, then approval from the railroad company must be obtained.

B. Spirals or Transition Curves

Spirals are not required in yards or industrial tracks.

C. Length of Curve

Maintain a minimum circular length of 50 feet regardless of speed.

2.4.2.4 SUPERELEVATION

Generally, not necessary for tracks in ICT yards or tracks designated for transporting freight, passenger cars, and other commodities such as scrap metal under the PANYNJ jurisdiction. However, if the need arises on a particular project, then superevelation shall conform to requirements as set forth in Chapter 5, Section 3.3 of AREMA's Manual for Railway Engineering.

2.4.2.5 VERTICAL ALIGNMENT

A. Vertical Curve

Absolute minimum length of curve is 50 feet. Desirable length shall be 100 feet or greater.

B. Vertical Gradient

Tracks within yard shall have 0% longitudinal grade. Gradients may be introduced with permission by the Chief Civil Engineer and the operating railroad.

2.4.2.6 TRACK CENTERS AND CLEARANCES

A. Track Centers

Track Centers shall be 14'-0" minimum, or greater if necessary. Increase the spacing of the track centers in accordance with the "Freight Track Minimum Track Centers for New Construction" tables below within limits of curvature, where minimum track centers is equal to 14'-0" + (degree of curvature times 2").

Freight Track Minimum Track Centers for New Construction

Type of Tracks	Degree of Curvature	Minimum Track Centers
Adjacent Main Tracks, Including Additional Main Tracks Or Adjacent Yard Lead Tracks Except Ladder Tracks	Tangent Track	14’-0”
	0°-30’	14’-1”
	1°-00’	14’-2”
	1°-30’	14’-3”
	2°-00’	14’-4”
	2°-30’	14’-5”
	3°-00’	14’-6”
	3°-30’	14’-7”
	4°-00’	14’-8”
	4°-30’	14’-9”
	5°-00’	14’-10”
	5°-30’	14’-11”
	6°-00’	15’-0”
	6°-30’	15’-1”
	7°-00’	15’-2”
	7°-30’	15’-3”
	8°-00’	15’-4”
	8°-30’	15’-5”
	9°-00’	15’-6”
	9°-30’	15’-7”
	10°-00’	15’-8”
	10°-30’	15’-9”
	11°-00’	15’-10”
	11°-30’	15’-11”
	12°-00’	16’-0”
	12°-30’	16’-1”
	13°-00’	16’-2”
	13°-30’	16’-3”
	14°-00’	16’-4”

Type of Tracks	Degree of Curvature	Minimum Track Centers
Parallel Yard Industrial Or Other Side Tracks Except Ladder Tracks	Tangent Track	14'-0"
	0°-30'	14'-1"
	1°-00'	14'-2"
	1°-30'	14'-3"
	2°-00'	14'-4"
	2°-30'	14'-5"
	3°-00'	14'-6"
	3°-30'	14'-7"
	4°-00'	14'-8"
	4°-30'	14'-9"
	5°-00'	14'-10"
	5°-30'	14'-11"
	6°-00'	15'-0"
	6°-30'	15'-1"
	7°-00'	15'-2"
	7°-30'	15'-3"
	8°-00'	15'-4"
	8°-30'	15'-5"
	9°-00'	15'-6"
	9°-30'	15'-7"
	10°-00'	15'-8"
	10°-30'	15'-9"
	11°-00'	15'-10"
	11°-30'	15'-11"
	12°-00'	16'-0"
	12°-30'	16'-1"
	13°-00'	16'-2"
	13°-30'	16'-3"
	14°-00'	16'-4"

Type of Tracks	Degree of Curvature	Minimum Track Centers
Main Track to Any Parallel Track Other Than Another Main Track Or A Ladder Track	Tangent Track	17'-0"
	0°-30'	17'-1"
	1°-00'	17'-2"
	1°-30'	17'-3"
	2°-00'	17'-4"
	2°-30'	17'-5"
	3°-00'	17'-6"
	3°-30'	17'-7"
	4°-00'	17'-8"
	4°-30'	17'-9"
	5°-00'	17'-10"
	5°-30'	17'-11"
	6°-00'	18'-0"
	6°-30'	18'-1"
	7°-00'	18'-2"
	7°-30'	18'-3"
	8°-00'	18'-4"
	8°-30'	18'-5"
	9°-00'	18'-6"
	9°-30'	18'-7"
	10°-00'	18'-8"
	10°-30'	18'-9"
	11°-00'	18'-10"
	11°-30'	18'-11"
	12°-00'	19'-0"
	12°-30'	19'-1"
	13°-00'	19'-2"
	13°-30'	19'-3"
	14°-00'	19'-4"

Type of Tracks	Degree of Curvature	Minimum Track Centers
Secondary, Running, or Passing Track to Any Parallel Yard Or Other Side Track Except Ladder Tracks	Tangent Track	17’-0”
	0°-30’	17’-1”
	1°-00’	17’-2”
	1°-30’	17’-3”
	2°-00’	17’-4”
	2°-30’	17’-5”
	3°-00’	17’-6”
	3°-30’	17’-7”
	4°-00’	17’-8”
	4°-30’	17’-9”
	5°-00’	17’-10”
	5°-30’	17’-11”
	6°-00’	18’-0”
	6°-30’	18’-1”
	7°-00’	18’-2”
	7°-30’	18’-3”
	8°-00’	18’-4”
	8°-30’	18’-5”
	9°-00’	18’-6”
	9°-30’	18’-7”
	10°-00’	18’-8”
	10°-30’	18’-9”
	11°-00’	18’-10”
	11°-30’	18’-11”
	12°-00’	19’-0”
	12°-30’	19’-1”
	13°-00’	19’-2”
	13°-30’	19’-3”
	14°-00’	19’-4”

Type of Tracks	Degree of Curvature	Minimum Track Centers
Ladder Track to Any Other Adjacent Parallel Track	Tangent Track	18'-0"
Two Adjacent Parallel Ladder Tracks	Tangent Track	19'-0"

Notes:

The track centers in the tables include a 1-inch increase for every 30 minutes of the degree of curvature. This increase is based on the assumption that both tracks have the same degree of curvature.

The track centers shown are based on zero superelevation or equal superelevation on both tracks. If the outer track has more superelevation than the inner track, the track centers shall be increased by 3 ½ inches per inch of difference in superelevation.

References:

American Railway Engineering and Maintenance-of-Way Association, *Manual for Railway Engineering* (2000), Volume 4, Chapter 28, Section 3.6, Table 3.3 "Legal Clearance Requirements by State (English Units)" pages 28-3-30 to 28-3-38.

Conrail, *Manual for Construction and Maintenance of Track – M. W. 4,* Part II, Construction and Maintenance Practice, Section 62.1, "Track centers. Eff. 3-77", page 14.

William W. Kratville, editor, *The Car and Locomotive Cyclopedia of American Practice* (Omaha: Simmons-Boardman Books, 1997), page 215. This contains "Plate H-Equipment Diagram for Double-Stack Container Cars"-AAR Standard S-2040-92, adopted 1991, revised 1992.

B. Clearances

Clearances shall conform to criteria as set forth in Chapter 28 of AREMA's Manual for Railway Engineering. If necessary, exceptions shall be approved by the operating railroad.

2.4.2.7 TURNOUTS AND CROSSOVERS

A. Split Switch Turnouts

1. No. 10 or No. 15 turnouts are desired
2. No. 8 turnouts are the minimum allowed.
3. Turnouts with curvature greater than No. 8 shall only be used with permission of the Chief Civil Engineer and the operating railroad.
4. Turnout design shall be as shown on the most current version of the Conrail Standard Plans.

B. Tongue - Mate Turnouts

1. Tongue and mate turnouts shall be used when necessary for paved track applications.
2. No. 10 or No. 15 turnouts are desired.
3. No. 8 turnouts are the minimum allowed.
4. Turnouts with curvature greater than No. 8 shall only be used with permission of the Chief Civil Engineer and the operating railroad.

2.4.2.8 TRACK STRUCTURE AND COMPONENTS

A. Ties shall be 7"x9"x8'-6" conforming to requirements of PANYNJ Technical Specification Section 341110 entitled "Railroad Trackwork".

B. Continuously Welded Rail shall be 136 RE conforming to AREMA standards. Use of any other rail size requires approval by the Chief Civil Engineer.

C. Tie plates and Fasteners

1. In ballasted track construction, unless otherwise requested by the operating railroad, rolled steel Pandrol plates with Pandrol e2055 clips are required.
2. Cast plates, cutspikes, and rail anchors may be used if requested by the operating railroad.

D. Spikes

Spikes may be either drive, screw, or lock types for Pandrol construction.

E. Ballast

1. Size graduation of ballast shall conform to AREMA's Manual for Railway Engineering, Chapter 1, Part 2, Table No. 1-2-2 for size No. 4 (or larger).
2. Physical properties of ballast shall conform to all requirements specified in AREMA's Manual for Railway Engineering, Chapter 1, Part 2, Table No. 1-2-1.

F. Roadbed or Sub-ballast

Roadbed, or sub-ballast, shall be a minimum of 8-inch thick unless soil conditions warrant greater thickness. Roadbed, or sub-ballast, shall conform to DGABC as per PANYNJ Technical Specification Section 321123 entitled "Aggregate Base Course".

2.4.2.9 Drainage

Proper drainage of track is highly important as it reduces maintenance and maintains overall structural integrity. In case of open track, runoff should be directed away from track and collected via ditches, swales, perforated subdrains, or combination thereof. Design of subdrains shall provide adequate drainage of the subbase layer and to provide water table suppression due to the increase in average precipitation or water table changes due to sea level rise. Refer to Design Guidelines - Climate Resilience chapter for sea level rise projections.

2.4.2.10 Grade Crossings

A. Asphalt Grade Crossings

1. Asphalt grade crossings with rubber railseal may be utilized in areas of predominantly automobile or light truck traffic.
2. Grade crossing shall comply with requirements as set forth in Chapter 5, Section 8 of AREMA's Manual for Railway Engineering.

B. Precast Concrete Grade Crossings

Precast concrete grade crossings shall be of the panelized type which does not require ties and ballast. Precast concrete grade crossings shall extend a minimum of one foot beyond the limits of the travelled way, or the shoulder if one is present. Grade crossing shall comply with requirements as set forth in Chapter 5, Section 8 of AREMA's Manual for Railway Engineering.

2.5 ELEMENTS OF DESIGN FOR PAVEMENTS

2.5.1 AIRFIELD PAVEMENTS

Criteria herein are applicable to the design of airfield pavements including runway, taxiway, apron, shoulder, and erosion pavements.

2.5.1.1 DESIGN PROCEDURES AND METHODOLOGIES

The design of flexible and rigid airfield pavements shall comply with FAA AC 150/5320-6F (or more recent if available) entitled "Airport Pavement Design and Evaluation" (hereafter AC). This AC fully implements the FAA's mechanistic design procedure which is performed using the FAA Rigid and Flexible Interactive Elastic Layer Design (FAARFIELD) computer program. The AC requires a 20-year structural life for pavements (i.e. flexible and rigid). The PANYNJ utilizes a 40-year structural life for a rigid pavement. Perform all airfield pavement designs or structural capacity evaluations using FAARFIELD.

A. Flexible Pavements

1. Mix Designs

Refer to the latest version of PANYNJ Technical Specification Section 321220 entitled "Asphalt Concrete Paving (FAA)" for the mix design requirements for airfield pavements.

a. The following table shows commonly used asphalt pavement mixes and the associated binder performance grade combinations along with their typical applications. This listing is for general use only and is to be used as a guide. The specific mix and performance is subject to approval by the Chief Civil Engineer.

Asphalt Concrete Mix & Asphalt Binder Performance Grade	Common Uses
Mix 1, PG 64-22	For use in the bottom courses of overlays as a less expensive alternative for top course material.
Mix 3, PG 64-22	For use outside runway keel sections except high speed exit areas and within shoulder and erosion areas.
Mix 3, PG 76-22 (Modified)	For use within runways and taxiways or within the traveled way of apron areas.
Mix 3, PG 82-22 (Modified)	For use within runway keel sections at the ends of runways and within keel sections of heavily queued taxiways or within the traveled way of apron areas.

b. The minimum thickness for the top course lift within the airfield is 3 inches, to provide stability under jet blast and to prevent shoving of the surface of runways in braking areas.

2. Design Parameters

The following is a general guide for assigning design parameters when designing a flexible pavement section using FAARFIELD. Sensitivity analyses should be performed for individual design parameters to ascertain their impact on the design.

a. The overlay surface layer for any flexible pavement design should be set as a P-401 AC Surface layer, with a modulus of 200,000 pounds per square inch (psi).

b. The bottom wearing course layer should be designed as a P-401 stabilized layer having a modulus of 400,000 psi.

c. Plant Mix Macadam layers should be located beneath the bottom wearing course layer and should be designed as an undefined layer having a modulus of 100,000 psi.

d. The base layer of the pavement should consist of DGABC and should be designed as a P-209 Crushed Aggregate layer, having a modulus of 75,000 psi.

e. When evaluating the adequacy of existing flexible pavement thickness, reduce the modulus of the existing pavement layers by a factor that is proportionate to its condition and estimated remaining useful remaining life. Refer to Figure 3, from "AASHTO Guide for Design of Pavement Structures," for a useful tool to determine the reduction factors based on remaining life.

f. Existing Lime Cement Flyash (LCF) concrete pavement shall be modeled as an undefined layer having a modulus of 1,000,000 psi when performing an overlay design.

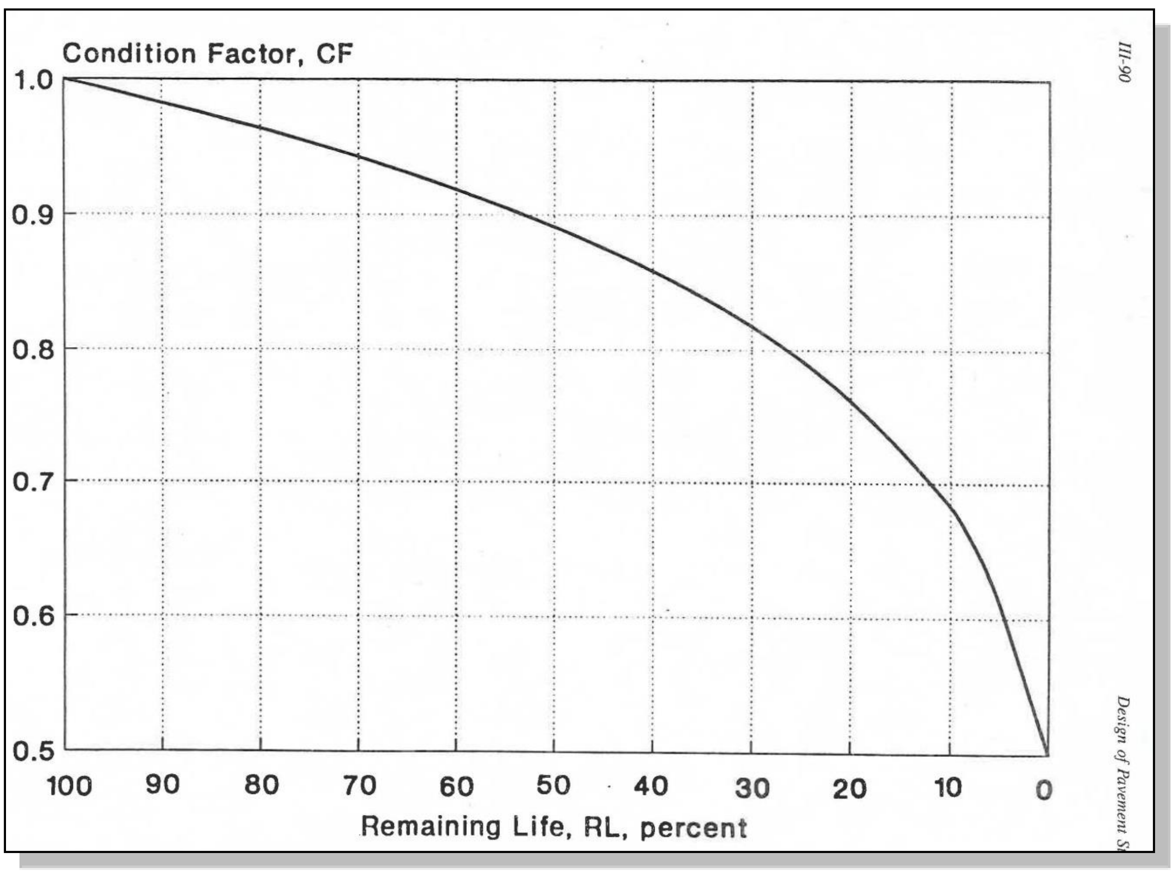

Figure 3
Relationship Between Condition Factor and Remaining Life

g. California Bearing Ratio (CBR)

The critical input for the subbase layer is the CBR, which FAARFIELD uses to calculate the subbase modulus. This value can vary within a given facility. For new taxiway or runway construction, consult with the Geotechnical Group to have borings taken to obtain precise CBR values.

- For average CBR values for EWR, JFK, and LGA refer to Figure 4.
- The design subgrade CBR value for TEB ranges between three and five. Due to this relatively low CBR range, a minimum of a 12-inch thick sand blanket layer is recommended beneath new taxiway pavements.
- The design subgrade CBR value for SWF has set to be established. Consult with the Geotechnical Group for advice.

h. Acquire the aircraft traffic mix and volumes from the PANYNJ Aviation Planning Division for use in performing final pavement designs. The aircraft traffic growth rate should be assumed as 1%, but must be confirmed by the PANYNJ Aviation Planning Division. Perform a sensitivity analysis when designing a pavement for a taxiway where projected volume is low since this volume may result in an under designed pavement section. Aircraft traffic mixes for JFK shall include A380 and 747-8 departures along routes designated for ADG VI. In the case of LGA, the gross take-off weights are restricted by the runway deck weight limitations. Obtain the gross take-off weights from the Structural Section of the Design Guidelines. The heaviest aircraft permitted at TEB is a DC-9-51 at 100,000 pounds.

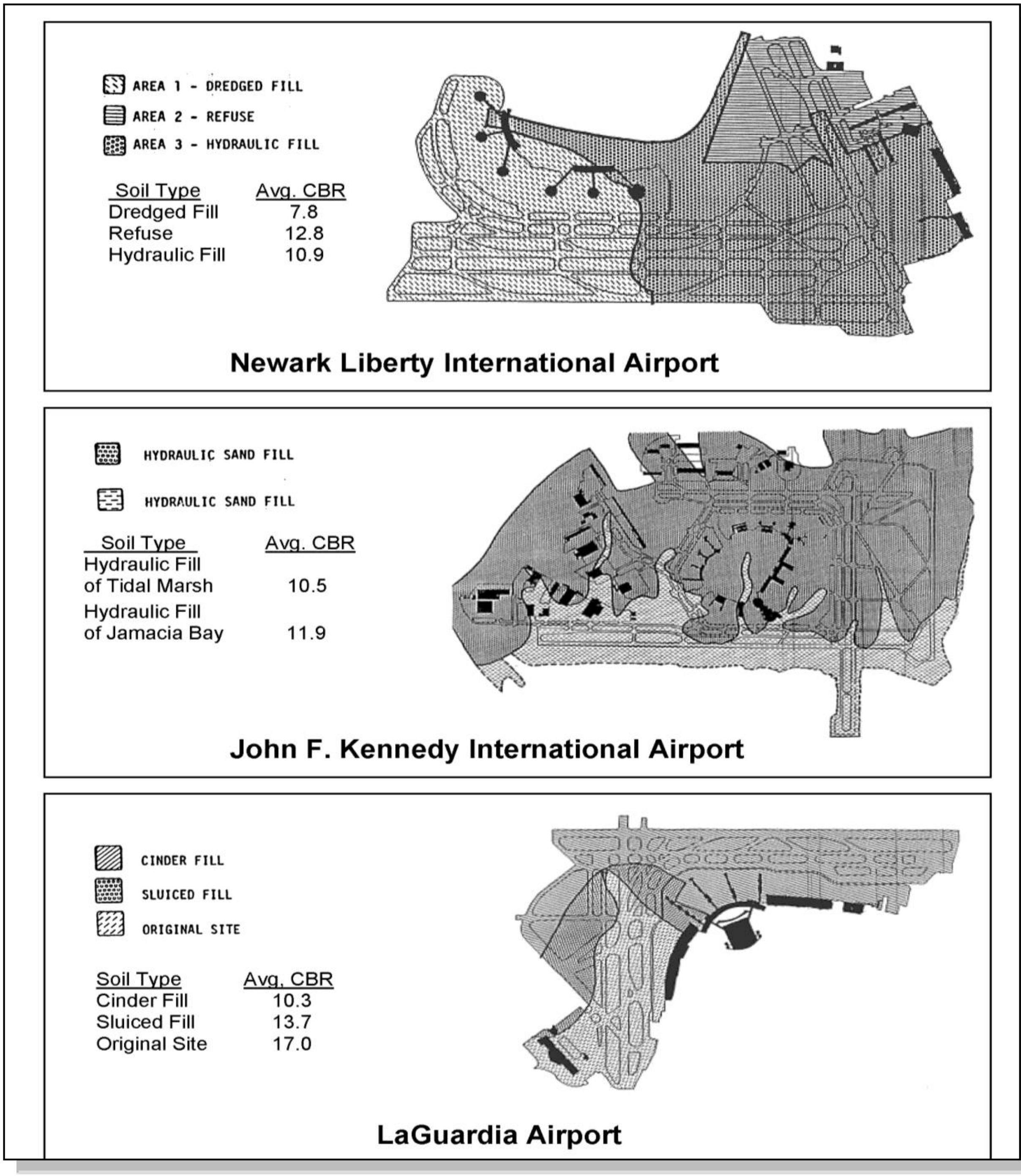

Figure 4
Average CBR Values for Newark Liberty International Airport, John F. Kennedy International Airport, and LaGuardia Airport

Note: These values were taken from the technical report, "Dynamic Characterization of Subgrade Soils at LaGuardia, Kennedy, and Newark Airports from Yang Deflection Data" by Pavement Consultancy Services – Advanced Technology Inc.

i. Provide subdrains adjacent to newly constructed flexible airfield pavements to ensure drainage of the pavement subbase layer and to provide water table suppression due to the increase in average precipitation or water table changes due to sea level rise. Refer to Airport Drainage Design (AC 150/5320-5D) for design guidelines on subsurface drainage design criteria and requirements.

3. Preliminary Flexible Pavements

For preliminary flexible pavements, refer to the PANYNJ Standard Details catalog for the standard flexible airfield pavement sections for a given airport facility. A design using FAARFIELD is required for design of all flexible pavements.

B. Rigid Pavements

1. Portland Cement Concrete (PCC) Mix Design

Refer to PANYNJ Technical Specification Section 033010 entitled “Portland Cement Concrete, Long Form” for PCC mix design requirements.

PCC Category	Common Use
I	For full-depth pavement and unbonded overlay within the airfield
II	For bonded overlay within the airfield

2. FAARFIELD Design Parameters

a. The surface layer for a new rigid pavement design should be set as a PCC surface layer with a flexural strength of 750 psi, unless concrete opening will be less than one week after placement.

b. A layer of Plant Mix Macadam (PMM) shall be placed beneath the PCC surface layer to allow for pavement drainage. This layer should be designed as an undefined layer having a modulus of 100,000 psi, with a typical thickness of 4”.

c. The bottom layer typically consists of a six-inch thick P-209 (DGABC) layer having a modulus of 75,000 psi.

d. The subgrade modulus can be expressed as the modulus of subgrade reaction *k* or as the elastic modulus *E* and can be input into FAARFIELD directly in either form. The conversion from CBR to *k*-value for the subgrade can be achieved using the following formula:

$$k = [1500\text{XCBR} / 26]^{0.7788} \text{ (pci)}$$

The conversion from *k*-value to the elastic modulus E can be achieved using the following formula:

$$E_{SG} = 26k^{1.284} \ (E_{SG} \text{ in psi})$$

e. Existing LCF pavement shall modeled as an undefined layer having a modulus of 1,000,000 psi.

3. Preliminary Rigid Pavements

a. For preliminary design purposes, the rigid airfield pavement sections for the various airport facilities are as follows:

Pavement Layer	Taxiways and Runways (JFK)	Taxiways and Runways (EWR)	Taxiways and Runways (LGA)
PCC (Category I)	20”	18”	16"
PMM	4”	4”	4"
DGABC	6”	6”	6"

Note: Design all final rigid pavement sections based on provided aircraft mix and volumes. These sections are based on the assumption of median range subgrade (CBR) values.

b. Subdrains shall be provided adjacent to rigid airfield pavements to provide drainage of the PMM base layer and to provide water table suppression. Refer to Airport Drainage Design (FAA AC 150/5320-5D) for design guidelines on subsurface drainage design criteria and requirements.

4. Portland Cement Concrete Slab Thickness

a. The thickened edge of a PCC slab shall be 1.25 times that of the design thickness, with a minimum of 2" in addition to the design thickness. The length of slab that has a thickened edge shall be equal to the design joint spacing of the pavement and the haunch length shall be equal to the 1/2 the slab length, with a minimum length of 10’. Slabs that have a thickened edge are used where traffic will traverse the edge of the pavement.

b. Where the edge of a rigid pavement abuts with a flexible pavement, and traffic will traverse this interface, a transition slab is used adjacent to the thickened edge of the rigid pavement. Refer to Figure 5 for the typical design dimensions of transition slabs.

5. Joint Design

The following is a general guide for the design of rigid airfield pavement joints.

a. Joint Types

- ❒ Provide an isolation joint between rigid pavements that have different axis of movement. Omit dowels for an isolation joint. In most cases, the exterior slabs along an isolation joint will have a thickened edge. Isolation joints may also be provided around penetrations in the rigid pavement.
- ❒ Provide contraction joints to control cracking due to a decrease in moisture content or a temperature drop as well as decrease stresses caused by slab warping. Contraction joints are typically orientated in the transverse direction.
- ❒ Provide construction joints to join slabs poured during different construction periods. These are typically orientated in the longitudinal direction but can also occur in the transverse direction.

b. Joint Spacing

- ❒ The spacing of transverse joints, in the longitudinal direction, shall be determined by calculating the required length of the slab.
  - A rough approximation for the length of a slab (L) feet, not having a stabilized base, is that it should not exceed twice the slab thickness (in inches). For a starting point when choosing the maximum joint spacing, refer to Table 3-9 of the AC.
  - The length of a slab (L in feet) having a stabilized base shall be at most six times the calculated Radius of Relative Stiffness (Rs), as defined by the following equation:

$$L = (6.0 * R_s)/12$$

Where (Rs), is defined by the following Westergaard equation:

$$Rs = \sqrt[4]{\frac{E * h^3}{12\left(1 - u^2\right) * k}}$$

Where: E = Modulus of elasticity, typically 5,000,000 psi.

h = slab thickness, inches.

u = Poisson's ratio for concrete, typically 0.15.

k = modulus of subgrade reaction, pci.

  - The maximum recommended slab joint spacing, for slabs thicker than 15 inches, is 25 feet.

- ❒ For unreinforced pavements, the ratio of slab length to width should not exceed 1.25.

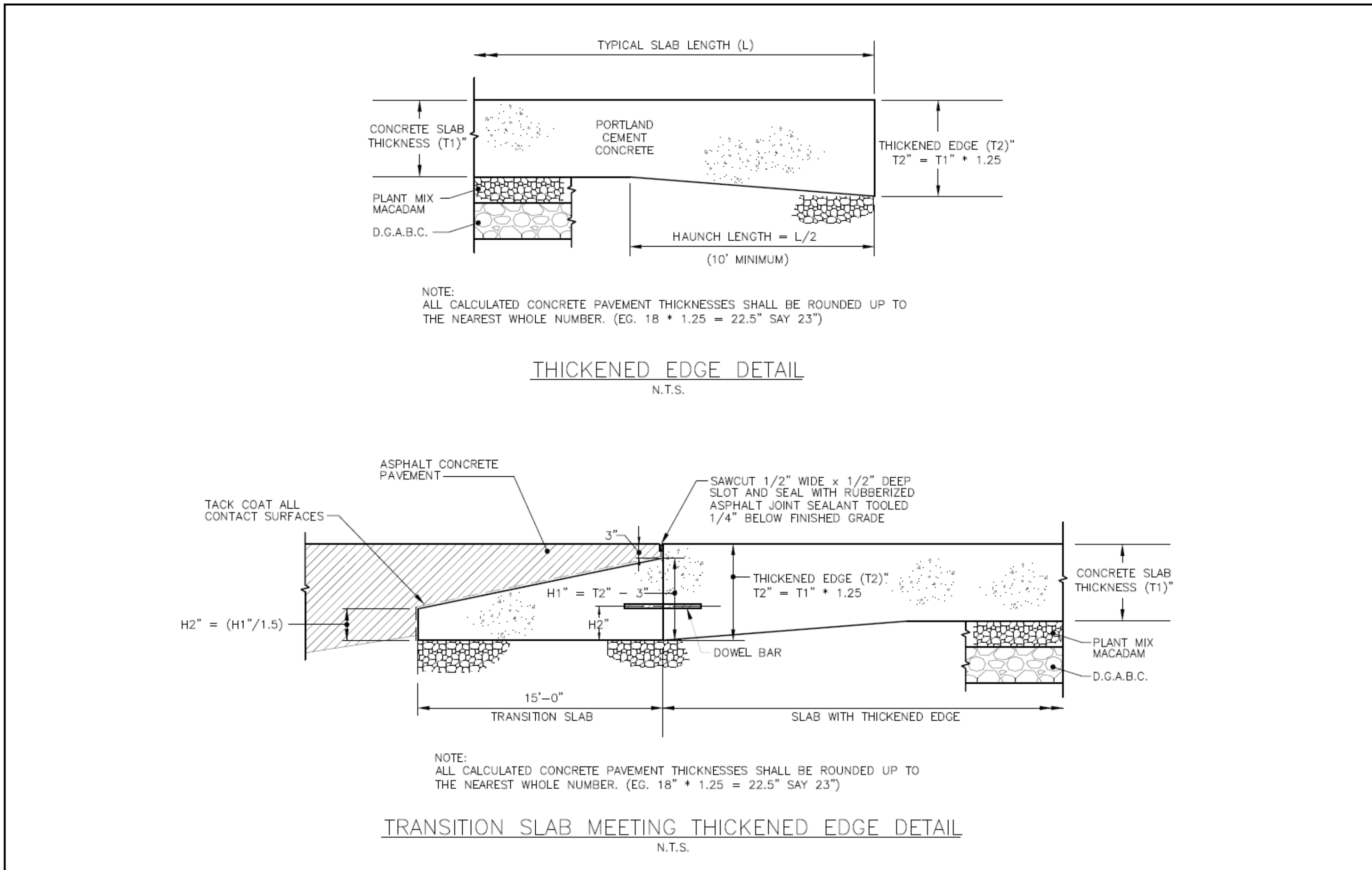

Figure 5
Typical Location of Slabs with a Thickened Edge

c. Joint Layout Pattern

Develop the joint layout pattern per Figure 3-16 of the AC subject to review by the PANYNJ.

d. Dowel Bar Design

Use Table 3-8 of the AC to select appropriate dowel bar dimensions and spacing based on the calculated thickness for the rigid pavement.

The bearing stress on the dowel bars is a function of the chosen size and spacing of the dowel bars and shall be checked against the allowable bearing stress of the concrete using the Friberg analysis. This calculation can be performed using the "Dowel Bar Design.xls $_{(5)}$"spreadsheet.

e. Joint Sealants

Joint sealants shall be rubberized asphalt or preformed elastomeric conforming to Technical Specification Section 321374 entitled "Pavement Joint Sealing". Provide appropriate details that comply with industry standards and manufacturer recommendations.

C. Pavement Rehabilitation

1. Design Parameters

a. Overlay pavements are grouped into four different types in the FAARFIELD program as follows:

- Hot Mix Asphalt Overlay of Existing Flexible Pavement
- Concrete Overlay of Existing Flexible Pavement
- Hot Mix Asphalt of Existing Rigid Pavement
- Concrete Overlay of Existing Rigid Pavement

b. Condition of Existing Pavement

- The existing pavement can be defined by assigning the layer types, the appropriate thicknesses, moduli of the existing layers, Structural Condition Index (SCI) and Cumulative Damage Factor Used (CDFU).
- When overlaying rigid pavement, determine the SCI of the existing rigid pavement based on the structural components of the Pavement Condition Index (PCI) method. SCI of 80 is the FAA definition of structural failure in a rigid pavement, and is consistent with 50% of slabs in a traffic area exhibiting a structural crack. If there is no visible deterioration in the existing rigid pavement (SCI = 100), the condition is described by the CDFU, which defines the amount of life that has been used by the existing pavement up to the time of the overlay.
- The design shall include appropriate details to ensure that severely distressed areas in the existing pavement are repaired prior to performing pavement rehabilitation.

2.5.2 VEHICULAR PAVEMENTS

Criteria herein are applicable to the design of vehicular pavements.

2.5.2.1 DESIGN PROCEDURES AND METHODOLOGIES

There are two main design methods for the design of flexible and rigid vehicular pavements.

A. Empirical Methods – Outlined in the following publications:

1. 1993 "AASHTO Guide for Design of Pavement Structures" and based on the AASHTO Road Tests performed between 1958 - 1961.
2. "1998 Supplement to the AASHTO Guide for Design of Pavement Structures, Part II, - Rigid Pavement Design & Rigid Pavement Joint Design."

B. Mechanistic Method – Outlined in the National Cooperative Highway Research Program 1-37A, "Mechanistic-Empirical Pavement Design Guide".

The design of vehicular pavement structures may be performed using either of these methods. The results of the Mechanistic Method should be back-checked with the Empirical Methods. The Mechanistic Method requires in-situ testing to determine the existing pavement material properties. Computations for the Empirical Method may be performed using the spreadsheets AASHTO Pavement Design-1993.xls (6) and AASHTO Rigid Pavement Design-1998.xls (7)

C. Vehicular Pavement Design Parameters

The following is a general guide for assigning design parameters, which are common to both flexible and rigid pavements, when designing a flexible pavement section using the AASHTO Empirical Method. Refer to Flexible Pavement Design Parameters and Rigid Pavement Design Parameters for additional design parameters. Sensitivity analyses should be performed for individual design parameters to ascertain their impact on the design.

1. Typical Reliability values are as follows:

Roadway Classification	AASHTO 1993 Reliability Range (%) For Urban Pavements	Suggested Reliability (%)
Interstate / Freeways	85 - 99.9	95
Principal Arterials	80 - 99	90
Minor Arterial, Collector	80 - 95	80
Local	50 - 80	70

2. A typical Terminal Serviceability Index (pt) is 2.5, which represents a "fair" roadway condition. A typical Initial Serviceability Index (po) is 4.5, which represents a "very good" roadway condition. These values result in a Serviceability Life of 2.0.
3. Typical values of Standard Deviation (So) values for various pavement types are as follows:

Pavement Type	So Range
Flexible	0.40 - 0.50
Rigid	0.35 - 0.40

4. The drainage coefficient for each pavement layer shall be assumed to have a value of 1.00. This is based on the assumptions that the pavement is exposed to high moisture levels approximately 25% of the time and the drainage condition is considered “good,” that is, water is removed within 1 day. This assumption is based on past climatic data for the New York/New Jersey region.

5. The latest traffic data should be acquired from the Traffic Engineering Unit for use in performing final pavement designs. The traffic growth rate should be assumed as 2%, unless a more realistic growth projection is available.

6. The following range of traffic distribution factors should be applied to multilane highway traffic counts to determine the traffic in the design lane. When dealing with high truck or bus volumes, consideration should be given to the percentage of these vehicles that are assumed to be in the design lane.

Number of Lanes	Percent of 18-kip EASL Traffic in Design Lane
1	100
2	80 - 100
3	60 - 80
4 or more	50 - 75

7. Some typical equivalent single axle load (ESAL) factors for various vehicles are as follows:

ESAL Factors		
Vehicle	Pavement Type	
	Flexible	Rigid
Passenger Car	0.0004	0.0002
Buses (Overall, half-full)	1.6	1.7
Trucks (Overall)	1.1	1.6

Note: When detailed information is known about the specific buses or trucks, which make up the traffic mix, ESAL factors should be calculated. These factors are not for use at GWB, GB, and port service roadways.

8. The modulus input for the subgrade layer shall be based on the CBR. A rough correlation between CBR and modulus as per AASHTO is: CBR X 1500 = Modulus

D. Flexible Pavements

1. Asphalt Concrete Mix Design

Refer to the latest version of PANYNJ Technical Specification 321217 entitled “Asphalt Concrete Paving” for the asphalt concrete mix design requirements for vehicular pavements.

a. The following is a list of commonly used asphalt concrete mixes and asphalt binder performance grades, along with their typical applications. This listing is for general use only and is to be used as a guide. The specific mix and performance is subject to approval by the Chief Civil Engineer.

Asphalt Concrete Mix	Common Use
Mix I-2A	Bottom course of overlay as a less expensive alternative for top course material
Mix I-4 or Mix I-5	Top (or wearing) course for secondary roadway, parking lot and in general service area. Variation of New Jersey Interagency Engineering Committee mixes are readily available
Mix I-4A	Top (or wearing) course for primary road subject to unusually heavy truck traffic
Mix I-5A	Top (or wearing) course for bridge deck
Mix I-6A	For use in lifts as thin as ¾ inches
Mix PA-5	Top (or wearing) course for primary and some secondary roadways

Asphalt Binder Performance Grade	Common Use
PG 64-22	Generally, a pavement subject to vehicular (minimal amount of trucks) traffic, parking lot, etc.
PG 76-22 (Modified Binder)	Generally, a pavement subject to heavy wheel loads (i.e. trucks), braking, and slow moving or channelized traffic
PG 82-22 (Modified Binder)	Reserved for unique condition

b. The minimum lift thickness for the wearing course shall be as specified in PANYNJ Technical Specification Section 321217 entitled “Asphalt Concrete Paving”.

2. Flexible Pavement Design Parameters

The following is a general guide for assigning design parameters when designing a flexible pavement section using the AASHTO Empirical Procedure. Refer to Paragraph 2.5.2.1.C for additional design parameters. Sensitivity analyses should be performed for individual design parameters to ascertain their impact on the design.

a. When calculating Load Equivalency Factors for flexible pavements, a common starting point assumption for values of the Structural Number (SN) and for the Terminal Serviceability Index (pt) are 5 and 2.5, respectively.

b. A typical flexible roadway pavement section contains an asphalt concrete wearing course layer, on a base layer of plant mix, beneath which lies a subbase layer of DGABC. The structural coefficients of these pavement layers are as follows:

Layer Material	Structural Layer Coefficient (Per Inch)
Asphalt Concrete (A.C.) Wearing Course Mix (I-4, I-5, I-6, I-2A)	0.44
PMM	0.20
DGABC	0.14

c. When evaluating the adequacy of the existing pavement thickness, assign Structural Layer Coefficients to the pavement layers that are representative of the surface condition and estimated remaining life, as per Figure 7 and Figure 8 from "AASHTO Guide for Design of Pavement Structures," 1993.

d. The typical design life for a flexible pavement is 20 years.

3. Typical Vehicular Flexible Pavement Sections

For preliminary design purposes, the typical pavement sections for vehicular applications are as follows:

Note: These typical flexible pavement sections shall be checked for adequacy, based on expected usage, using approved methods, prior to incorporation into contract drawings. These sections are based on the assumption of median range subgrade values.

Pavement Layer	Roadway	Bus Route (Within Parking Lot)	Parking Lot
	Thickness (in.)	Thickness (in.)	Thickness (in.)
A.C. Wearing Course	3 to 4	2	2
PMM	6	4	-----
DGABC	6	6	6

Note: These typical flexible pavement sections shall be checked for adequacy, based on expected usage, using approved methods, prior to incorporation into contract drawings. These sections are based on the assumption of median range subgrade values.

Table 5.2. Suggested Layer Coefficients for Existing AC Pavement Layer Materials

MATERIAL	SURFACE CONDITION	COEFFICIENT
AC Surface	Little or no alligator cracking and/or only low-severity transverse cracking	0.35 to 0.40
	<10 percent low-severity alligator cracking and/or <5 percent medium- and high-severity transverse cracking	0.25 to 0.35
	>10 percent low-severity alligator cracking and/or <10 percent medium-severity alligator cracking and/or >5–10 percent medium- and high-severity transverse cracking	0.20 to 0.30
	>10 percent medium-severity alligator cracking and/or <10 percent high-severity alligator cracking and/or >10 percent medium- and high-severity transverse cracking	0.14 to 0.20
	>10 percent high-severity alligator cracking and/or >10 percent high-severity transverse cracking	0.08 to 0.15
Stabilized Base	Little or no alligator cracking and/or only low-severity transverse cracking	0.20 to 0.35
	<10 percent low-severity alligator cracking and/or <5 percent medium- and high-severity transverse cracking	0.15 to 0.25
	>10 percent low-severity alligator cracking and/or <10 percent medium-severity alligator cracking and/or >5–10 percent medium- and high-severity transverse cracking	0.15 to 0.20
	>10 percent medium-severity alligator cracking and/or <10 percent high-severity alligator cracking and/or >10 percent medium- and high-severity transverse cracking	0.10 to 0.20
	>10 percent high-severity alligator cracking and/or >10 percent high-severity transverse cracking	0.08 to 0.15
Granular Base or Subbase	No evidence of pumping, degradation, or contamination by fines	0.10 to 0.14
	Some evidence of pumping, degradation, or contamination by fines	0.00 to 0.10

Figure 7
Suggested Layer Coefficients for Existing AC Pavement Layer Materials

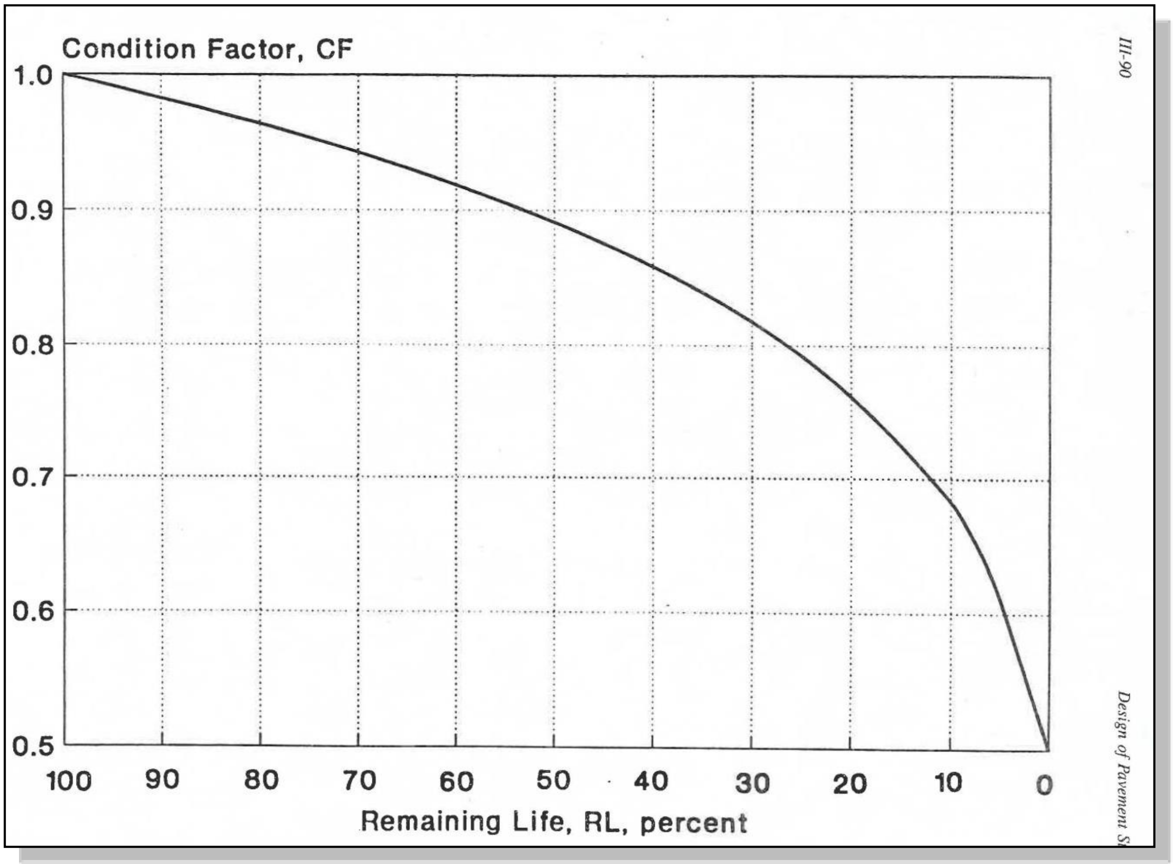

Figure 8
Relationship Between Condition Factor and Remaining Life

E. Rigid Pavements

1. Portland Cement Concrete (PCC) Mix Design

Refer to PANYNJ Technical Specification Section 033010 entitled "Portland Cement Concrete, Long Form" for PCC mix design requirements.

PCC Category	Common Use
I	Full-depth pavements and unbonded overlays within roadways or parking areas
II	Bonded overlays within roadways or parking areas

2. Rigid Pavement Design Parameters

The design of rigid vehicular pavements shall be performed in compliance with the "1998 Supplement to the AASHTO Guide for Design of Pavement Structures, Part II, - Rigid Pavement Design & Rigid Pavement Joint Design," using the AASHTO Rigid Pavement Design-1998.xls spreadsheet, which uses the design and analysis procedure outlined in this publication. The results of these computations should be back-checked against those calculated by using the 1993 AASHTO empirical Rigid Design Nomograph using AASHTO Pavement Design-1993.xls spreadsheet. Refer to Paragraph 2.5.2.1.C for additional design parameters. Sensitivity analyses should be performed for individual design parameters to ascertain their impact on the design.

a. When calculating Load Equivalency Factors for rigid pavements, a common starting point assumption for values of the Slab Thickness (D) and for the Terminal Serviceability Index (pt) are 10 and 2.5, respectively.

b. The value for Modulus of Rupture (Mr) shall be equal to the flexural strength of the PCC layer (Category I) which is currently 700 psi as specified in PA Technical Specification Section 033010 entitled "Portland Cement Concrete, Long Form".

c. The typical modulus of concrete is 4,000,000 psi.

d. Values of Modulus of Subgrade Reaction (k) can be determined by using a rough correlation with the CBR value. The following correlations were taken from "Pavement Analysis and Design," by Yang H. Huang:

CBR	Modulus of Subgrade Reaction (k)
3	100
5.5	150
10	200
20	250
50	500

a. Values for Load Transfer Coefficient (J) shall be as follows:

Doweled		Not Doweled	
Edge Support	No Edge Support	Edge Support	No Edge Support
2.7	3.2	2.8 - 3.6	3.2 – 4.3

b. The typical design life for a rigid pavement is 40 years.

3. Vehicular Rigid Pavement Sections

For preliminary design purposes, the typical pavement sections for some vehicular applications are as follows:

Pavement Layer	Roadway Thickness (in.)
PCC	10 to 12
DGABC	6

Note: These typical flexible pavement sections shall be checked for adequacy, based on expected usage, using approved methods, prior to incorporation into contract drawings. These sections are based on the assumption of median range subgrade values.

4. Joint Design

The following is a general guide for the design of rigid vehicular pavement joints.

a. Joint Types (Refer Joint Types for design criteria).

b. Joint Spacing

❒ The spacing between transverse contraction joints is a function of the designated roadway lane width. Roadway lane widths typically vary between 12 feet and 14 feet for roadways, and are around 15 feet for toll plaza lanes.

❒ For unreinforced pavements, the ratio of slab length to width should not exceed 1.25.

❒ Refer to Joint Spacing for additional techniques to determine joint spacing.

c. Joint Layout

❒ It is desirable to align longitudinal joints with pavement markings.

❒ All longitudinal and transverse contraction joints shall be doweled.

❒ Refer to Joint Layout for additional criteria.

d. Dowel Design (Refer to Dowel Bar Design for design criteria).

e. Joint Sealants (Refer to Joint Sealants for design criteria).

F. Permeable Pavement

1. Design Parameters

The following is general design guidelines for permeable pavement. Refer to New York State Stormwater Management Design Manual Chapter 5.3.11 Porous Pavement for additional design parameters.

a. Permeable pavement is designed to infiltrate rainfall through the surface, reducing storm water runoff from a site. Permeable paving also increases the recharge of groundwater through infiltration and provides some pollutant uptake in the underlying soils.

b. Permeable pavement shall be considered for low traffic volume roads and parking lots. High traffic volume areas, high dust areas, and areas with heavy truck traffic are not recommended.

c. Due to the possibility of groundwater contamination through stormwater infiltration, permeable paving is not recommended for areas with highly contaminated runoff such as fueling stations, high-use commercial parking lots and ports.

d. Permeable paving is generally designed to accommodate a 1-inch or less design storm.

e. The subgrade soil permeability shall be between 0.5 and 3.0 inches per hour for permeable paving.

f. The Permeable pavement shall be located at least 3 feet above the seasonally high groundwater table.

g. Permeable paving can be used effectively in cold-climate areas, but sand or other materials shall not be applied for winter traction as they quickly clog the pavement.

2.5.3 MAINTENANCE OVERLAYS

2.5.3.1 GENERAL

A. When performing maintenance overlay design, the adequacy of the existing pavement shall be evaluated using approved methods.

B. Allow for two opportunities of attaining grade control, whenever possible, i.e. mill the pavement surface based on the finished grades prior to overlay, as opposed to milling a general depth, prior to overlay. This is more critical for the pavements of runways and arterial highways to promote smoothness.

1. When performing "straight" overlays, consider that a general rule for crack propagation through an overlaid pavement is about an inch per year without the application of a membrane.

2.5.3.2 FLEXIBLE PAVEMENT

If the existing surface is to be raised by a 0.03 feet or more, due to an overlay, all utility castings shall be adjusted.

2.5.3.3 RIGID PAVEMENT

A. After the application of an asphalt concrete overlay on an existing rigid pavement, sawcut joints in the asphalt concrete overlay to control reflective cracking. Replicate the joint pattern of the existing rigid pavement. The dimension of the sawcut joints shall be ½" x ½" and filled with rubberized asphalt.

B. When applying an unbounded rigid overlay of a rigid pavement, provide a thin asphalt concrete overlay between the pavements to act as a "bond breaker."

C. When the bottom of pavement removal lies within LCF concrete pavement, provide a waterproofing membrane to protect the LCF from water infiltration.

2.6 ELEMENTS OF DESIGN FOR STORMWATER DRAINAGE SYSTEM

2.6.1 GENERAL

A. Analysis of an existing PANYNJ facility stormwater drainage system is required only if additional demand will be imposed on the stormwater drainage system, or modifications are proposed.

B. When a connection to, or a modification of, an existing stormwater drainage system not under the PANYNJ jurisdiction is required, then comply with all applicable requirements or criteria of the regulating agency.

C. As much as possible, preserve overall drainage patterns both upstream and downstream from the project site.

D. Check to ensure that the existing downstream structures, or systems, have adequate capacity and are not adversely affected by the proposed modification.

2.6.2 WATER QUALITY

A. New York facilities

1. If the development of a project site requires disturbing more than one acre of land, develop calculations and documentation delineating pre-development and post-development pervious and impervious surfaces. Coordinate with the Environmental Discipline at project kick-off to generate required calculations and information for the Notice of Intent for Construction Activity and Stormwater Pollution Prevention Plan. Design and implement any necessary non-structural and/or manufactured structural water quality control system(s) in accordance with the New York State Stormwater Management Design Manual.

B. New Jersey facilities

1. If the development of a project site requires disturbing one or more acre(s) of land, develop calculations and documentation delineating pre-development and post-development pervious and impervious surfaces. Compare the post-development to the pre-development to demonstrate if the post-development results in a net increase of less than one-quarter acre of impervious surface. Coordinate with the Environmental Discipline at project kick-off to ensure identification of applicable stormwater quality permits.
2. If the development of a project site requires increasing impervious surface by one-quarter acre or more, coordinate with the Environmental Engineering Unit at project kick-off to develop calculations and documentation for a Stormwater Engineering Report. Implement non-structural and/or manufactured structural water quality control devices in accordance with the most recent version of New Jersey Stormwater Best Management Practices Manual.
3. For comprehensive stormwater quality requirements at the PA's New Jersey facilities, refer to Stormwater Management Rules at N.J.A.C. 7:8. The water quality treatment facilities and design shall be determined in accordance with the most recent version of New Jersey Stormwater Best Management Practices Manual.

C. Post-Construction Maintenance of Manufactured Structural Water Quality Control Devices

Ensure that all maintenance and operations manuals supplied by the manufacturer are submitted to the Facility per PANYNJ Technical Specification Section 334914 entitled “Manholes and Drainage Structures”. These manuals are to be turned over to the facility at the time of substantial completion.

2.6.3 WATER QUANTITY

A. Level of Protection (LOP)

1. An area where minor alteration(s) to the existing drainage patterns are proposed shall demonstrate that there will be no increase in storm water quantity in the existing stormwater drainage system due to the project work; or if there is an increase, that there will be no increased risk of inundation.
2. An area where major alteration(s) to the existing drainage patterns are proposed shall demonstrate that the 10-year storm water quantity can be reliably conveyed.
3. An entirely new stormwater drainage system shall demonstrate that a minimum 10-year storm water quantity can be reliably conveyed.
4. Design for a stormwater drainage system in a project area of proposed major alteration(s) that include depressed roadways shall demonstrate that the 50-year storm water quantity can be reliably conveyed.
5. Design for a stormwater drainage system in areas that are critical to the operation and emergency management may be required to demonstrate that a higher storm water quantity can be reliably conveyed, as determined by the Chief Civil Engineer.

B. Quantity of surface runoff from sites 200 acres or less in size can be computed using the Rational Method or the National Resource Conservation Service Technical Release 55 method.

1. Peak runoff by the Rational method:

$$Q = CiA$$

Where: Q = Peak discharge (cfs)

C = Runoff coefficient

i = Rainfall intensity (in/hr)

A = Catchment area (acres)

2. Where runoff quantity (volume) and/or time-dependent flows are needed, use an approved method to produce runoff hydrographs such as National Resource Conservation Services, British Road Research Modified Rational Method, Illinois Urban Drainage Area Simulator, etc. Parameters used for these methods, such as time of concentration, slope, imperviousness, hydraulic length, etc., shall be determined in the appropriate manner for the specific method utilized.
3. Runoff coefficients for use with the Rational Method:

Surface Type	Runoff Coefficient
Roofs and asphalt and concrete pavements	0.98
Grass or vegetated areas having slopes up to 2%	0.10
Grass or vegetated areas having slopes greater than 2%	0.15

Note: Runoff coefficient for other surface types can be found in HEC-22 Urban Drainage Design Manual Table 3-1

4. Time of concentration

Time of Concentration for the Rational Method shall be the longer of the minimum time of overland flow based on the facility type or the sum of the overland and channelized travel times within consecutive flow segments.

Facility Type	Recommended Time of Concentration T_C (minutes)				
	Overall Min.	Surface Type	Sheet Flow	Shallow Flow	Channel Flow
Marine Terminals, Parking Lots, Roadways	10	Unpaved n=0.15, k=0.457	$\frac{0.94\, L^{0.6} n^{0.6}}{i^{0.4} S^{0.3}}$	$\frac{L}{60k(100S)^{0.5}}$	See Manning's Eqn.
		Paved n=0.011, k=0.619			
FAA, , All Other	5	Unpaved n=0.15, k=0.457			
		Paved n=0.011, k=0.619			

Where: k = intercept coefficient

n = Manning's coefficient

L = Length of flow Segment (feet)

S = Average Slope of HGL (ground) in Flow Segment (feet/feet)

C. Length of sheet flow is generally less than 150 feet, but can be up to 300 feet in smooth, uniformly graded, areas.

D. Historically, time of concentration was determined from the overall time of overland flow developed by the Corps of Engineers, given by:

$$T_C = \frac{1.8(1.1 - C)L^{0.5}}{S^{0.333}}$$

E. Regional Rainfall Intensity:

a. Use the below tables to create IDF curves for New York and New Jersey facilities.

b. Historically, rainfall intensity (i) was established the following equations:

NY: $i = 120/(T_C + 20)$; NJ: $i = 96/(T_C + 15)$.

c. Other approved methods, such as synthetic or actual rainfall hyetographs may be used to determine rainfall intensity.

NY Facilities (Except SWF) Precipitation Intensity Duration and Return Period								
Return Period	5 Minute	10 Minute	15 Minute	20 Minute	25 Minute	30 Minute	45 Minute	60 Minute
2-Yr	4.99	3.86	3.17	2.66	2.35	2.14	1.60	1.32
5-Yr	5.86	4.52	3.74	3.15	2.80	2.57	1.94	1.63
10-Yr	6.68	5.14	4.25	3.61	3.22	2.97	2.27	1.92
25-Yr	7.98	6.08	5.04	4.32	3.89	3.60	2.78	2.37
50-Yr	9.12	6.93	5.76	4.95	4.46	4.14	3.23	2.78
100-Yr	10.49	7.91	6.62	5.70	5.14	4.77	3.77	3.28

SWF Precipitation Intensity Duration and Return Period								
Return Period	5 Minute	10 Minute	15 Minute	20 Minute	25 Minute	30 Minute	45 Minute	60 Minute
2-Yr	4.64	3.59	2.94	2.47	2.18	1.99	1.48	1.23
5-Yr	5.46	4.22	3.49	2.94	2.61	2.39	1.81	1.52
10-Yr	6.25	4.80	3.97	3.37	3.01	2.77	2.12	1.79
25-Yr	7.49	5.71	4.73	4.06	3.65	3.38	2.61	2.22
50-Yr	8.58	6.52	5.42	4.66	4.20	3.89	3.05	2.62
100-Yr	9.92	7.49	6.26	5.39	4.86	4.52	3.57	3.10

NJ Facilities Precipitation Intensity Duration and Return Period								
Return Period	5 Minute	10 Minute	15 Minute	20 Minute	25 Minute	30 Minute	45 Minute	60 Minute
2-Yr	4.84	3.83	3.18	2.76	2.42	2.17	1.66	1.35
5-Yr	5.74	4.55	3.80	3.34	2.96	2.66	2.06	1.70
10-Yr	6.42	5.08	4.24	3.77	3.35	3.02	2.35	1.95
25-Yr	7.28	5.71	4.78	4.33	3.86	3.49	2.76	2.30
50-Yr	7.88	6.18	5.18	4.71	4.21	3.83	3.04	2.57
100-Yr	8.53	6.64	5.56	5.11	4.58	4.17	3.35	2.84

2.6.4 Design Parameters

A. Performance of Stormwater Drainage System

1. For curbed roadways, the stormwater drainage system shall permit the gutter to convey storm water runoff without spreading to more than 1/3 of the adjacent traveled lane. Water shall not overtop curb or encroach into developed property.
2. In critical areas, the hydraulic grade line under peak flow conditions may rise to one foot below the minimum gutter elevation.
3. For aeronautical areas (i.e., runways, taxiways, aprons), for a return period of greater than 5-years, excess flows are permitted to pond in areas between runways, taxiways, and aprons. Ponding is not permitted to extend into a runway or taxiway.
4. For open paved parking areas, marine cargo storage, pedestrian plazas, etc. the drainage system shall have capacity for direct runoff with no accumulation other than overland and gutter flows. For a return period greater than 10 years, ponding is permitted to a depth that will not cause excessive damage or a threat to public safety but generally to less than one foot

B. Catchment Layout:

1. For the PANYNJ standard catch basins, limit the area of runoff to 1 acre.
2. For roadways; Catch basins should be located at the low points of gutters, including flanking catch basins, at intersections and ramp exit/entrances, before transitions of super elevation (to prevent water flow across the roadway), before bridges (in cut), and after bridges (in fill). Spacing should not exceed 350 feet.
3. For curbed roadways, the inlet spacing typically controls catchment areas, which is required to control "spread." The gutter flow can be computed using the applicable [Manning's equation] below. (See Reference 4.4 Drainage Inlet Design in Hydraulic Engineering Circular (HEC)-22 Urban Drainage Design Manual).

$$Q = \frac{0.56}{n}(S_x^{1.67} S_L^{0.5} W^{2.67})$$

or in terms of spread, $W = \left(\frac{Qn}{0.56 S_x^{1.67} S_L^{0.5}}\right)^{0.375}$

where: n = Manning's coefficient (Table 4-3 Manning's n for Street and Pavement Gutters in HEC-22 Urban Drainage Design Manual)

Q = flow rate (cfs),

W = width of flow or spread (feet)

S_x = cross slope (feet/feet)

S_L = longitudinal slope, feet/feet

C. Locate manholes at all major changes in pipe grade, at all changes in horizontal alignment, and at all changes in pipe size, and should have a maximum spacing of 300 feet for pipe 24 inches or less in size, 400 feet for pipe 27 to 36 inches in size, 500 feet for pipe 42 to 54 inches in size and 1000 feet for pipe 60 inches or greater in size.

D. Up to three catch basins may be connected in series before discharging into a manhole except as otherwise indicated in NFPA #415.

E. In aircraft apron areas, new catch basins must be located 100 feet minimum away from buildings and must be protected with gas-tight vapor traps on the outlet.

F. Catch Basins Associated with Runways and Taxiways (Reference: Memorandum from Muldoon to J.M. Kelly; 7/31/87; same subject):

1. FAA current design standards call for the placement of catch basins beyond runway and taxiway safety area.
2. Relocating existing catch basins solely for compliance with current FAA criteria is determined on a case-by-case basis. Where a basin must be relocated for other reasons, it shall comply with the criteria herein.
3. For EWR, TEB, SWF, and JFK:
    a. Locate catch basins associated with new runway construction (including extensions) beyond the runway safety area.
    b. Locate catch basins associated with new taxiway construction (excluding extensions) beyond the taxiway safety area.
    c. Catch basins may be placed in taxiway shoulders only when existing taxiways are extended. In this regard, it is proper to place catch basins within the taxiway safety area since this is an extension of an existing taxiway covered by previous FAA criteria.

1. Bridge Deck Drainage:
    a. The minimum criteria for drainage of elevated roadways are established to maintain safe conditions by providing a proper LOP to facilitate safe passage of vehicles and to minimize frequency of maintenance forces being exposed to traffic hazards. Accordingly, these criteria shall not be violated without substantial justification as approved by the Chief Civil Engineer.
    b. Designs shall be based on specified limitation of spread for a design rainfall intensity selected using the Rational Method, avoidance of hydroplaning, and driver vision impairment. See FHWA Bridge Deck Drainage, HEC-21 (Ref. 5.4).
    c. Locate catch basins prior to the bridge approach slabs to intercept any flows onto the bridge. The preferred design is for bridge deck drainage to flow (by gutter) off of the bridge (i.e., no drainage system on the bridge) and conveyed by a closed drainage system.
    d. Design bridge deck drainage systems to minimize clogging in order to reduce related safety, maintenance, etc., problems (see FHWA Bridge Deck Drainage, HEC-21)
        1) Grates shall be bicycle-safe type with a desirable minimum capacity of twice the design flow and shall be easily removable for maintenance.
        2) Inlet boxes shall be large enough for easy cleaning with the outlet offset to prevent debris from falling into it.
        3) Pipes shall have a desirable minimum diameter of 8 inches and an absolute minimum diameter of 6 inches. For systems utilizing closely spaced holes in the deck, the pipe diameter may be as small as 4 inches and shall be tapered to prevent trapping of debris.
        4) Bends shall be long radius-type fittings and not greater than 45 degrees.
        5) Pipe slopes shall be as steep as possible with a desirable minimum of 8% and an absolute minimum of 2%.
        6) Provide for clean-outs that are accessible.

7) The design shall include a report on maintenance cleaning procedures and equipment upon which the design is based, and which shall be approved by the appropriate facility maintenance representative.

2.6.5 Hydraulic Design

2.6.5.1 Design Conduit Flow

Assuming steady-state conditions, using the Manning formula:

$$V = (1.49/n)\,(R^{2/3})\,(S^{1/2})$$

$$Q = (1.49/n)\,(A)\,(R^{2/3})\,(S^{1/2})$$

Where: V = Average velocity (feet/sec)

R = Hydraulic radius = A/P (feet)

S = Slope of HGL for open channel flow and of EGL for pipe flow (feet/feet)

n = Manning roughness co-efficient

A = Cross-sectional area (ft^2)

P = Wetted perimeter (feet)

Q = Flow (cubic feet per second)

Manning Roughness Coefficients (n):

Type of Pipe	Manning Roughness Coefficient New or Existing Pipe
Concrete	0.013
Ductile iron with cement lining	0.013
High-density polyethylene with smooth wall interior	0.012
High-density polyethylene with corrugated interior	See manufacturer literature
Plastic	0.011
Corrugated metal	See manufacturer literature

2.6.5.2 Velocity of Flow Within Pipes

- Maximum 10 feet/sec
- Minimum 2.5 feet/sec
- For FAA projects, the minimum velocity shall be 3.0 feet/sec in storm drain pipe flowing full. The minimum pipe slopes to ensure 3.0 feet/sec velocity can be found in Table 6-4 in AC 150/5320-5D.
- Remain constant or increase as flow progresses downstream.

2.6.5.3 Hydraulic Grade Line (HGL)

HGL at tidal outfalls shall equal the elevation of Mean High Water (MHW). The tidal datum height must be adjusted to reflect the rise in sea level due to climate change. Refer to the Climate Resilience Design Guidelines.

2.6.5.4 Minimum Pipe Size

The minimum pipe size, excluding roof connections, shall be 12 inches in diameter except in aeronautical (PAF) areas where minimum size shall be 15 inches in diameter. Pipe sizes shall either remain constant or increase in size in the downstream direction.

2.6.6 Standard Method

2.6.6.1 Design Procedure and Assumptions

A. Compute peak discharge using the Rational Method.

B. Design pipes to flow full using Manning's formula. Then, and if necessary, use software, such as StormCAD or Hydraflow Storm Sewers, to calculate the elevation of the HGL to finalize the pipes.

C. For new drainage systems, which include new outfalls in tidal water, use elevation of MHW as the starting elevation of the HGL.

D. When a new drainage system is required to connect to an existing system, use the crown elevation of the existing pipe as starting elevation of the HGL to analyze the upstream effects of the new drainage system.

E. Manhole losses including a limited number and magnitude of bends are not considered. These losses are assumed to be accounted for by matching pipe soffits and by designing for full flow.

F. Insofar as possible, match pipe soffits (top inside) when changing sizes. Where this cannot be achieved for trunk sewers, manhole and head losses shall be considered.

2.6.6.2 Uses of the Standard Method

A. The PANYNJ facilities are generally in flat, low-lying topography and are located near or adjacent to tidal (bay, river) receiving waters. Drainage systems have flat pipe slopes (for economy and to avoid submerged outfalls), resulting in sub-critical flows throughout.

B. The method is also recommended for preliminary design of more complex systems.

2.6.6.3 Limitations of Standard Method

A. Restricted to simple drainage systems that do not require pumping, ponding, storage, or open channels.

B. Advanced software methods are readily available and may be used, subject to approval of the Chief Civil Engineer.

2.6.7 Miscellaneous

A. Use of trench drains or slotted drains require approval by the Chief Civil Engineer. Please note that slotted drains are susceptible to clogging and require frequent maintenance.

B. Open channel systems like riprap, grass swale design are to follow U.S. Department of Transportation Federal Highway Administration Hydraulic Design Series No. 3 guideline.

C. Depressed catch basin curb inlets in non-high speed areas shall be depressed 0.1 feet below adjacent pavement grades. All other grates in paved areas shall be set flush with the pavement grade. In unpaved areas, the grate shall be set 1 inch above the surrounding grade unless otherwise dictated by site-specific conditions.

D. All catch basins and manholes shall conform to the type and dimensions shown on the appropriate PANYNJ standard details.

E. The standard bedding for stormwater pipe is six minimum crushed stone bedding below the pipe. It may be necessary to provide alternative bedding (e.g. concrete pipe saddles) where the Geotechnical Engineer anticipates significant differential settlement. See PANYNJ standard details for bedding requirements.

F. Pipe Materials:

1. All pipe materials shall conform to the type specified in PANYNJ standard technical Specification Section entitled "Stormwater Drainage System". Use of other materials is subject to prior approval by the Chief Civil Engineer.
2. Use extra-strength (Special Thickness Class 56) ductile iron pipe whenever a 24-inch or smaller connection is made to a New York City-owned sewer that is located on city property.
3. Use circular pipes except when conditions make use of circular pipe impractical.
4. Generally, the minimum cover for any type of pipe shall be 3 feet below grade in aeronautical areas and 2 feet below grade in all other areas, or 1 foot below pavement subgrade, whichever is deeper. Confirm adequacy of cover using standard design procedures typically found in the Concrete Pipe Design Manual, Ductile Iron Pipe Association's literature, or Plastic Pipe Design methodologies. Additionally, at manholes, perform necessary calculations to ensure that all pipes have sufficient depth of cover to clear the bottom of the top slab.

G. The drainage systems must be protected with gas-tight vapor traps on the outlet whenever it discharges into an existing combined sewer system, where the pipe goes through contaminated areas, or where water tight joints are necessary to preserve the operating integrity of a storm water system protected with tide gates.

H. Retention or detention basins may be utilized, with prior approval from the Chief Civil Engineer, to reduce peak stormwater inflow into existing limited capacity stormwater drainage systems. Shallow ponding in paved areas will be considered, provided it can be demonstrated that the limited ponding will neither create hazards for persons using the area nor cause damage to existing or proposed structures. A hydrograph method of analysis is required for the design of the retention basins. (Rate of inflow – rate of outflow = rate of change of storage.)

I. Grass or bio swales may be considered along roadsides to enhance water infiltration and reduce erosion where applicable.

J. Where the construction has the potential for changing the existing off-facility drainage conditions, the engineer shall document historical flood data (which includes but is not limited to pictorial and survey data of high flood marks on pertinent structures with notations of associated storms) and establish the impact that the new construction will have on same (for example, the tail water versus head water effect on drainage structures). Where off-facility drainage affects urban areas, check for conditions based upon 100-year design storm.

K. Channel erosion and scour shall be minimized through the use of protective materials and devices incorporated into the design, including:

1. Cut-off walls at the discharge end of culverts and outfalls to prevent undermining.
2. Paved or stone aprons at discharge end of culverts and outfalls following Standards for Soil Erosion and Sediment Control in New Jersey and New York.

3. Bank protection on the outside of horizontal curves where stream velocity can cause erosion of soils.

2.7 Elements of Design for Water Supply System

2.7.1 General

A. An analysis of an existing PANYNJ facility water supply system is required only if additional demand (e.g. a new terminal) will be imposed on the water supply system(s), or modifications are proposed.

B. Criteria herein are applicable to exterior, potable water supply systems for domestic and/or fires uses.

C. New water mains shall be ductile iron pipe (4 inch or larger) and conform to PANYNJ standard technical Specification Section entitled “Exterior Water Supply System”. Plastic pipe is not permitted.

D. Comply with local municipal water authority and boards of public health for potable water.

2.7.2 Hydraulic Design

A. Design using the steady-state conditions based upon peak flow rates using the Hazen-Williams formula.

$$V = 1.318\ CR^{0.63}\ S^{0.54}$$

Where: C = 140 for new cement-lined pipe

C = 150 for new epoxy-coated pipe

C = Varies for existing pipe, see Table 1.

R = Hydraulic radius (feet)

S = Slope of hydraulic grade line (feet/feet)

V = Average velocity (feet/sec)

B. Estimate losses at fittings, valves, and other appurtenances using an equivalent pipe length based on the equation:

$$h_L = kv^2/2g$$

Where: h_L = Head loss (feet)

v = Flow velocity (feet/sec)

g = Acceleration of gravity = 32.2 feet/s^2

k = Loss coefficient for specific bend, fitting or appurtenance is found in Table 2.

C. When required, perform analysis of the water supply system using Hardy-Cross Method of design or American Water Works Association (AWWA) recommended procedure. Use of computer software, such as WaterCAD by Bentley Systems is also acceptable.

D. Per recommendation from the Ductile Iron Pipe Research Association (DIPRA) do not exceed a design velocity of 14 feet/second under peak day demand conditions.

Table 1
Value of C in Hazen-Williams Equation

Type	Condition	Size	C
Cast Iron	New	All sizes	130
	5 Years old	12” and over	120
		8”	119
		4”	118
	10 Years old	24” and over	113
		12”	111
		4”	107
	20 Years old	24” and over	100
		12”	96
		4”	89
	30 Years old	30” and over	90
		16”	87
		4”	75
	40 Years old	30” and over	83
		16”	80
		4”	64
	50 Years old	40” and over	77
		24”	74
		4”	55
Welded Steel	Values of C the same as for cast-iron, 5 years older		
Riveted Steel	Values of C the same as for cast-iron, 10 years older		
Ductile Iron (Cement-Lined)	Average value, regardless of age		120-140
Concrete or concrete Lined	Large sizes, good workmanship, steel forms		140
	Large sizes, good workmanship, wooden forms		120
	Centrifugally spun		135

$$h_{LP} = \frac{4.73\,L\,Q^{1.852}}{C^{1.852}\,D^{4.87}}$$ (Hazen Williams Equation English Units)

SOURCE: Haestead Methods Cybernet Users Manual, V. 2, July 1992; TABLE I Values of C in Hazen Williams Equation

Table 2
Loss Coefficients for Common Fittings

Fitting	M
Globe valve, fully open	10.0
Angle valve, fully open	5.0
Swing check valve, fully open	2.5
Gate Valve, fully open	0.2
Gate valve, ¾ open	1.0
Gate valve, ½ open	5.6
Gate valve, ¼ open	24.0
Short-radius elbow	0.9
Medium-radius elbow	0.8
Long-radius elbow	0.6
45 Elbow	0.4
Closed return bend	2.2
Tee, through side outlet	1.8
Tee, straight run	0.3
Coupling	0.3
45 Wye, through side outlet	0.8
45 Wye, straight run	0.3
Entrance	
Square	0.5
Bell mouth	0.1
Re-entrant	0.9
Exit	1.0

$$h_{LM} = M \frac{V^2}{2g}$$

SOURCE: HAESTEAD METHODS CYBERNET USERS MANUAL, V. 2, July 1992; TABLE III MINOR LOSS COEFFICIENTS.

9/2/97

2.7.3 THRUST RESTRAIN

A. Provide restraint against thrust forces using restrained or harnessed joints or reinforced concrete encasement. Use of concrete thrust blocks for permanent or temporary restraint is permitted if approved by the Chief Civil Engineer.

B. Restrain all water pipes against thrust forces at fittings 11¼ degrees and greater, tees, caps, plugs, fire hydrants, valves, cross fitting where a pipe is discontinued at any leg of the cross fitting, under railroad tracks, under building floors, and under taxiways and runways.

C. Compute thrust forces and resistance thereto using AWWA or other accepted procedures such as those available from DIPRA. Consult with the Geotechnical Discipline to obtain necessary soil properties and consult manufacturer's literature for properties of specialized pipe joint restraint systems.

2.7.4 SYSTEM CAPACITY

A. Water demand should take into account the current peak demand as well as the anticipated demand. Additionally, the quantity of water required for fire flow conditions, as provided by the Chief Mechanical Engineer.

B. Design for a minimum residual pressure of 20 psi at all times in the water supply system when the fire flow conditions are superimposed on the normal daily water demand. Normal pressures in the water supply system should range between 50 to 80 psi. System design pressure shall consider most hydraulically demanding load on service supply.

C. Review high-pressure water supply systems with the Fire Protection Engineer for high-risk fire flow demand and size accordingly.

D. Base commercial and industrial demand on historical PANYNJ demand for similar systems or per acre/per capita estimates or other approved methods, if more accurate data does not exist.

E. Pipe size for individual building service connections (domestic and sprinkler) and other mechanical/fire service connections shall be as requested by the Mechanical Engineering Discipline.

2.7.5 MISCELLANEOUS

A. Provide a check valve or pressure reduction valve when connecting to a water supply system having a different pressure. Additionally, a gate valve is required on inlet and outlet of check valve or pressure reduction valve. These installations typically require a concrete chamber with proper access for maintenance and inspection.

B. In accordance with the Engineering Department Chief Engineer's memorandum dated April 21, 2000 and as per New York City Building Code and Fire Code and International Building Code New Jersey edition connections to public mains or source of water supply require a backflow prevention assembly. Consult with the Mechanical Discipline.

C. The standard bedding for water pipe is six minimum crushed stone bedding below the pipe. It may be necessary to provide alternative bedding (e.g. concrete pipe saddles) where the Geotechnical Engineer anticipates significant differential settlement. See PANYNJ standard details for bedding requirements.

D. PA Technical Specifications require that polyethylene encasement be installed with ductile iron pipe installations. Polyethylene encasement provides a cost effective way of precluding corrosion of the ductile iron pipe in typical installed conditions. While not common, alternative protection may be necessary if stray electrical currents are expected or known (i.e. PATH or NYC Subway). Consult with the Electrical Discipline.

E. Avoid locating water mains under footings, foundations, or structures. Ensure that PANYNJ Standard Detail 030.021 is included if any water main is required to cross below or above an existing pipe or obstruction.

2.7.6 LAYOUT

A. The minimum diameter of pipe for a primary water main is 8 inches.

B. Desirable minimum depth of cover for frost protection is 4 feet with an absolute minimum of 3 feet. For depth of cover of less than 3 feet, protect the pipe and appurtenances against frost by insulation or other means.

C. All segments of the distribution system shall be fed from a minimum of two directions.

D. Design water mains to cross above sanitary sewer lines and fuel lines insofar as possible. The vertical separation of these lines at crossings, joint locations, encasement requirements, and lateral separation at locations other than crossings shall meet the current State Board of Health requirements.

E. Fire Hydrants

1. Maintain existing fire hydrants. If it is necessary to remove an existing hydrant, then ensure that adequate fire protection is maintained, including replacing or adding additional fire hydrant(s).
2. If an area of a facility that is to be redeveloped or significantly modified, or any new property, the location of fire hydrants shall be as approved by the Mechanical Discipline’s fire protection engineer as well as Risk Management. In any case, comply with applicable NFPA standards, municipality requirements, and New York City Building Code (for NYC facilities). In no case shall any building area be more than 300 feet from a fire hydrant.
3. For areas designated for stacking of containers with container terminals or within intermodal yards, at a minimum, locate fire hydrants adjacent to high mast light poles and protect against damage. Protection may include heavy-duty (8 inch or greater diameter) concrete filled pipe guards or guide rail.
4. Connect fire hydrants to the distribution main with a minimum 6-inch diameter pipe that includes a valve and valve box. The valve and valve box should be located within 6 feet of the fire hydrant. An additional valve and valve box is required adjacent to the distribution main when the distance between the fire hydrant and distribution main exceeds 50 feet.
5. Fire hydrants shall conform to the type specified in PANYNJ standard technical Specification Section entitled “Exterior Water Supply System” and PANYNJ standard details.

F. Valves

1. Provide valves at the point of connection whenever a new pipe is added onto the water supply system.
2. Provide valves at the intersection of all branch lines so that each branch can be isolated out of service as required. A desirable maximum number of two valves should isolate any portion of the water supply system.

3. The desired maximum spacing between valves for 16-inch or larger diameter mains is 1000 feet. For 12-inch or smaller diameter mains and distribution lines the desired maximum spacing is 500 feet.
4. Provide an air relief valve at major low points in the water supply system and shall be piped to a storm sewer.
5. Valves, including valve boxes, shall conform to the type specified in PANYNJ standard technical Specification Section entitled “Exterior Water Supply System” and PANYNJ standard details.

2.8 ELEMENTS OF DESIGN FOR SANITARY SEWER

2.8.1 GENERAL

A. PANYNJ sanitary sewers generally consist of small-diameter (18 inches and below) circular pipes serving as building sewer connection, lateral, or main sewers.

B. Comply with all applicable requirements of the governmental agencies, which have jurisdiction where the sewer is constructed.

2.8.2 QUANTITY OF SEWAGE

A. The preferred method for estimating peak sewage flow for building sewer connection is the "fixture unit" method unless otherwise advised by the Chief Mechanical Engineer. Coordinate with design of building plumbing.

B. The peak sewage flow shall include an allowance for infiltration which depends on the type and length of sewer, soil, groundwater, and topographic conditions. The minimum rate for a new system shall be twice the allowable rate of the pipe as constructed (see PANYNJ Technical Specifications) or 400 gpd/inch dia/mile, whichever is greater.

2.8.3 HYDRAULIC DESIGN

A. Design pipes assuming steady, uniform flow using the Manning equation.

1. Manning Equation

$$V = (1.49/n)\, R^{2/3}\, S^{1/2}$$

$$Q = AV$$

Where: V = Average velocity (feet/sec)

Q = Flow (ft^3/sec)

A = Cross-section Area of flow (ft^2)

S = Slope of energy grade line (feet/feet)

R = Hydraulic Radius A/P (feet)

P = Wetted Perimeter (feet)

n = Manning Roughness Coefficient (0.013).

B. Size pipes to flow half-full, or less, at the design peak flow. Do not design the pipe to flow full.

1. The half-full velocity shall be:

   a. Desirable minimum: 2.5 feet/sec

   b. Absolute minimum: 2.0 feet/sec with prior approval of the Chief Civil Engineer.

   c. Maximum: 10 feet/sec

   d. Velocities within any pipe network shall either remain constant, or increase, as the flow progresses in the downstream direction.

   e. Whenever the velocity within the system exceeds 6 feet/sec at a manhole, design the manhole structure to obtain a smooth transition in the hydraulic grade line across the structure.

C. The minimum pipe diameter for building sewer connection shall be 6 inches except use 8 inches in Manhattan. For smaller size pipes, consult with Mechanical Engineering Group for advice. Pipe size shall either remain constant or increase in size in the direction of flow. Where pipe diameters increase, it is desirable to match the pipe soffit elevations.

D. Flows through manholes are treated as minor losses and uniform flow is assumed on both sides. The invert elevation of the outlet pipe within each manhole shall be a minimum of 0.1 feet below the elevation of the lowest inlet pipe invert elevation entering the manhole to account of energy losses across the appurtenance.

E. Most PANYNJ sanitary sewer systems are characterized by relatively low flows and flat topography. This generally means that minimum size and velocity requirements are the controlling design factors. Such systems generally operate with sub-critical flow at considerably less than pipe capacity. Lift stations are used to offset costs and problems associated with excessively deep sewers.

2.8.4 Pipe Materials and Manhole Structures

2.8.4.1 Pipe Materials

A. All pipe materials shall conform to the type specified in PANYNJ standard technical Specification Section entitled “Exterior Sanitary Sewer Gravity System”. Use of other materials is subject to prior approval by the Chief Civil Engineer.

B. Use ductile iron pipe where excessive loading conditions occur due to a minimum depth-of-bury condition, at all stream crossings, at locations where pipe will be within 10 feet of a stream embankment, and for all 24-inch or less connection to New York City sewers.

C. All materials used shall be sulfide and hydrocarbon (fuel and oil) resistant and shall be designed for a 50-year service life. Where corrosive sewage is anticipated, provide special linings and/or coatings to ensure a 50-year service life.

D. The depth of the sewer shall be governed by structural (i.e. live and dead loads) requirements and depths of connecting tributary pipes. The minimum cover over any pipe shall be 3.0 feet below grade or 1.0 feet below the pavement subgrade, whichever is deeper.

2.8.4.2 Manhole Structures

A. All manholes shall conform to the type and dimensions shown on the appropriate PANYNJ standard details.

B. Provide a manhole at the end of each sewer line, at all pipeline intersections, at all changes in grade or alignment, and whenever pipe sizes change.

C. Manholes should have a maximum spacing of 300 feet for 15 inches and smaller lines, and a maximum spacing of 500 feet for 18 inches and larger size lines.

D. Provide drop manholes or lateral sewers entering into the manhole whenever the invert difference between lateral and main sewers exceeds 4 feet.

E. A building sewer connection 6 inch, or less, in diameter may be made using wyes or tees set so that the connection will be at a point 45 degrees to the horizontal plane in the upper quadrant of the lateral sewer. Provide a manhole for building sewer connection greater than 6 inch.

F. Clean-outs may be substituted, as approved by the Chief Civil Engineer, in lieu of manholes at all changes in grade or alignment on building sewer connections only.

2.8.5 MISCELLANEOUS

A. Force mains shall be ductile iron pipe only, conforming to ANSI A21.51. and shall be designed at two times the normal working pressure.

B. The standard bedding for sanitary sewer pipe is six minimum crushed stone bedding below the pipe. It may be necessary to provide alternative bedding (e.g. concrete pipe saddles) where the Geotechnical Engineer anticipates significant differential settlement. See PANYNJ standard details for bedding requirements.

C. Where sewers traverse an area that may contain stray electrical currents (e.g. PATH) provide appropriate corrosion protection.

D. Design sanitary sewer lines to cross under water mains insofar as possible. The vertical separation of these lines at crossings, joint locations, encasement requirements, and lateral separation at locations other than crossings shall meet the current state Board of Health requirements.

E. Building floor drain effluents contributing petroleum-based oil and grease in amounts that exceed the allowable limit set by applicable regulations shall be processed using an approved oil/water separator to meet the prescribed limits before discharging into the sewer.

F. Provide grease traps in accordance with applicable regulations in waste lines servicing food service areas.

G. Provide watertight manhole covers and alternate venting in areas where the top of the sanitary manhole would be subject to flooding (e.g. manholes located below the 100-year floodplain or in areas that will be inundated by the increase in sea level rise or in areas subject to localized rainfall-related ponding). Refer to the Climate Resilience Design Guidelines for the base flood elevation (BFE) and sea level rise projection.

2.9 ELEMENTS OF DESIGN FOR GAS UTILITY

Gas service is the responsibility of the utility company. The utility company will dictate all design and project requirements.

2.10 HORIZONTAL AND VERTICAL CONTROLS

2.10.1 GENERAL

A. Horizontal and vertical controls for surveying, mapping, and engineering documents are provided and maintained by the PANYNJ Central Survey Group (CSG). Contact the CSG for the appropriate horizontal and vertical controls for the corresponding PANYNJ facility.

B. For assistance in converting between different horizontal or verticals controls, contact the CSG.

C. When appropriate, reference the horizontal and vertical controls in contract documents, reports, studies and other design documents.

2.10.2 TIDAL DATA

A. The tidal data using standard tidal planes of reference (tidal datums), and with the datum referenced to the PANYNJ vertical datum (NAVD88), shall appear where it is of significance to the planning, design, construction, or operation of the facility.

B. A tidal datum is a standard elevation defined by a certain phase of the tide. Tidal datum is used as reference to measure local water levels and should not be extended into areas having differing oceanographic characteristics without substantiating measurements. Definitions for different tidal datums can be found at the NOAA Website [(8).]

C. The National Oceanic and Atmospheric Administration (NOAA) [(9)] maintains tidal stations in the port area, including four primary stations (NY-The Battery, NJ-Sandy Hook, NY-Bergen Point West Reach and NY-Kings Point) which are analyzed for an entire 18.6-year lunar cycle (Tidal Epoch). Other stations are Secondary (6 months) or Tertiary (30 days), and are of less accuracy.

D. Local tidal datum information at each PANYNJ Facility has been calculated by the PANYNJ Central Survey Group using the NOAA VDatum program (Vertical Datum Transformation software). Contact the CSG for the tidal datum data sheets. Additional Tidal information (such as tide prediction tables) can be obtained from NOAA Center for Operational Oceanographic Products and Services Branch (Tides&Currents) [(10)]

E. Tide varies by location and for certain civil design projects a local tide gauge may need to be installed and observed. Contact the CSG for this survey task. For critical or major projects consult with the PANYNJ Chief Civil Engineer for the method of tidal datum determination.

F. For planning and design of new facilities, incorporate sea level rise. Refer to the Climate Resilience Design Guidelines for sea level rise projections due to climate change.

2.11 EXCEPTIONS

2.11.1 QUALIFICATIONS FOR AN EXCEPTION

When conditions warrant, a design exception may be granted. A design exception may be approved when it can be documented that a lesser design value is the best practical alternative. The factors to be considered when determining if a lesser design value should be elected shall include social, economic, and environmental impacts together with ensuring safe and efficient operations.

2.11.2 PROCEDURE

Prior to implementing the design exception, submit a written request to the Chief Civil Engineer for approval. Clearly state the reason for the design exception and include all supporting documentation as necessary to substantiate the design exception.

3.0 SUPPLEMENTAL LITERATURE

3.1 AIRCRAFT SIMULATION ANALYSIS

- APR Consultants; Computer Program "Take-off" version 1.0; 1993.

3.2 GEOMETRIC DESIGN

- A Policy of Geometric Design of Highway and Streets (Green Book), American Association of State Highway and Transportation Officials (AASHTO).
- Roadside Design Guide (RDG), American Association of State Highway and Transportation Officials (AASHTO).
- Guide for the Development of Bicycle Facilities (Bike Guide), American Association of State Highway and Transportation Officials (AASHTO).
- Guide for the Planning, Design and Operation of Pedestrian Facilities, American Association of State Highway and Transportation Officials (AASHTO).

3.3 SANITARY SEWERS

- ASCE/WPF; Gravity Sanitary Sewer Design and Construction; Manual No. 60/FD5.

3.4 STORMWATER DRAINAGE

- ASCE; Manuals and Reports on Engineering Practice Nos. 28 (2nd Ed.), 37 and 77.
- FAA; Airport Drainage; AC 150/5320.
- AASHTO; Highway Drainage Guidelines; 1987.
- AASHTO: Drainage Manual; Draft; 1990.
- FHWA; Hydraulic Engineering Circulars Nos. 5; 10 & 13 (dealing with culverts); AND 12; Drainage of Highway Pavements.
- FHWA; Bridge Deck Drainage Guidelines: 1986; Report No. FHWA /RD-87/014 (N.T.I.S.P.B. 87-178364).
- T.R.B.; Bridge Drainage Systems; N.C.H.R.P. Synthesis of Highway Practice No. 67; 1979.
- A.P.W.A.; Urban Stormwater Management: Special Report No. 49; 1981.
- N.Y.S.D.E.C.; Reducing the impacts of Stormwater Runoff from New Development; 1992.
- N.Y.C.E.P.A.; Design Criteria and Procedures for the Preparation of Drainage Plans; 1973.
- F.H.W.A.; Bridge Deck Drainage; HEC-21; May 1993.
- N.J.D.E.P./U.S.G.S.; Stankowski; Magnitude and Frequency of Floods, in New Jersey with Effects of Urbanization; Special Report 38; 1994.

3.5 WATER SUPPLY

- NFPA 415; Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways.
- NFPA 307; Standard for the Construction and Fire Protection of Marine Terminals, piers, and Wharves.

4.0 LINKS

1. [Online] http://www.panynj.gov/business-opportunities/pdf/discipline-guidelines/climate-resilience.pdf. 2.

2. [Online] \\Patccsrv1\cad\ENG\Divisions\Civil\PATH References\REFERENCE,STD DTLS,SPECS,CAR DATA\PATH STD Manuals. 18.

3. [Online] \\Patccsrv1\cad\ENG\Divisions\Civil\PATH References\REFERENCE,STD DTLS,SPECS,CAR DATA\PATH STD Manuals\17-07-28 PATH TRACK STD MANUAL-Final. 18.

4. [Online] \\Patccsrv1\cad\ENG\Divisions\Civil\PATH References\REFERENCE,STD DTLS,SPECS,CAR DATA\TRACK CHARTS\PATH TRACK CHARTS 2007-2009 COMPLETE. 23.

5. [Online] \\Patccsrv1\cad\ENG\Divisions\Civil\-- Civil Design Guidelines\Civil Reference Document\3.5.1.1.B.5.d-Dowel Bar Design.xls. 45.

6. [Online] \\Patccsrv1\cad\ENG\Divisions\Civil\-- Civil Design Guidelines\Civil Reference Document\3.5.2.1.B and E-AASHTO Pavement Design-1993.xls. 48.

7. [Online] \\Patccsrv1\cad\ENG\Divisions\Civil\-- Civil Design Guidelines\Civil Reference Document\3.5.2.1.B and E-AASHTO Rigid Pavement Design-1998.xls. 46.

8. [Online] http://tidesandcurrents.noaa.gov/datum_options.html. 73.

9. [Online] https://oceanservice.noaa.gov/. 73.

10. [Online] https://tidesandcurrents.noaa.gov/products.html. 73.