FUNCTIONAL AND TECHNICAL SPECIFICATIONS
DEEP INJECTION WELL

PREPARED FOR

CARNIVAL GRAND PORT FACILITY
FREEPORT, GRAND BAHAMA

PREPARED BY

R. C. MINNING & ASSOCIATES, INC.
TREASURE ISLAND, FLORIDA

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1.0 OBJECTIVE

This document defines the functional and technical specifications, and general construction considerations for the construction of a deep injection well at the Carnival Grand Port Facility, Freeport, Bahamas.

2.0 SCOPE

These guidelines apply to one (1) deep well to be constructed for the disposal of treated permeate from the Membrane-Bioreactor (wastewater treatment plant), reverse osmosis water treatment plant concentrate and discharge (backwash) from the water amenities, these combined flow streams are referred to as the injected fluid.

3.0 GENERAL CRITERIA

Guidelines are in general conformance with the document ***Deep Well Disposal for the Bahamas*** as developed by the Water and Sewerage Corporation – Water Resources Management Unit (May 2004). Injection wells should be designed, constructed and maintained in such a manner as to: (1) protect the quality of underground sources of drinking water; (2) eliminate the impact of the operations at other facilities in the area and/or residential neighbors; and, (3) ensure that the injected fluid remains in the injection zone.

4.0 ASSUMPTIONS

4.1 Construction of wells under the guidelines contained in this document presumes that a geotechnical evaluation has been conducted at the proposed injection site and has determined that the location is suitable for injection of treated/untreated injected fluid.

4.2 Construction and continued operation of wells per these guidelines presumes that injection occurs in a transmissive zone which lies well below a confining zone in the non-potable water layer, and migration of the injected fluid out of the injection zone, and into unapproved regions or other aquifers is prohibited.

4.3 Monitoring of the groundwater quality is required to ensure that there is no contamination of the freshwater / brackish water lens by the injected fluid.

An adequate number of the monitoring wells are required in appropriate locations, and to sufficient depths to allow proper and effective analysis of the groundwater conditions. The design and construction considerations for monitoring wells are not covered in this document.

5.0 PROCESS REQUIREMENTS

5.1 Capacity

The system shall be designed for an average injection flow rate of 391.25 gallons per minute (gpm), with a fluid velocity of 5 ft./sec. under normal operating conditions.

Flow	WWTP Permeate	SWRO Concentrate	SWRO Backwash	Amenity Discharge
Design, gpd	30,000	390,000	30,144	7,200
Annual Flow, gallons	7,665,000	99,645,000		
Maximum Daily, gpd	45,000	390,000		
Peak Instantaneous, gpm per contributor	31.25	280	251.2	360
Peak Instantaneous flow to well, gpm[(1)]				391.25

.[(1)] Amenity discharge and SWRO Backwash are periodic activities that will be scheduled when the SWRO plant is not operating, therefore the peak flow to the well will be the largest of these flows plus the potential WWTP Permeate.

5.2 Injected Fluid Characteristics

The characteristics of each injection stream are shown below. The combined injected fluid stream will be a clear liquid with the following maximum concentrations (in mg/L) based on an annualized loading.

Parameter	WWTP Permeate	SWRO Concentrate	SWRO Backwash	Amenity Discharge	Composite
TSS	2	2	35	<35	2.01
TN	10	0	0	10	0.65
BOD_5	10	2	10	<35	2.53
TP	6	0	0	2	0.39
TDS	500	55,600	30,144	500	52,010
Chlorine	1.2	0	0	1	0.08
Fecal Coliform	<25 MPN			<25 MPN	<25 MPN

5.3 Process Flow

Effluent streams will be generated from the: (1) Membrane-Bioreactor - permeate; (2) discharge and backwash from the Reverse Osmosis water treatment plant - concentrate; and, (3) backwash from the water amenities. The clear treated permeate will be stored and used for irrigation and excess will be directly injected. The SWRO concentrate will be directly injected. The backwash from the water amenities will be filtered and then directly injected on a staggered basis.

6.0 HYDROLOGIC AND GEOLOGIC CONSIDERATIONS

Actual hydrogeologic conditions must be delineated and verified prior to well construction to depth of injection. A driller's log shall be prepared to total depth providing a description of the material encountered for every five (5) feet of penetration and/or change in formation, the down pressure on the drill bit in pounds per square inch (psi), and fluid pressure in psi. A borehole video camera survey and hole caliper log shall be run to verify the condition of the drilled borehole, the nature of the material adjacent to the borehole, depth of fractures and apparent porosity, verification of casing installation and grouting. These logs will be used to determine final well depth, construction and verification of well completion. It is critical that a confining zone be identified that will restrict fluid flow. Further, the injection zone must be sufficiently transmissive to accept the injected fluid with ease, and without plugging over time.

7.0 SPECIFICATIONS

7.1 **Injection Well**

7.1.1 Completion Method

The bottom hole completion of the injection well shall be by the open-hole completion method. The final depth of the well, as well as the thickness of the injection zone will be determined from the driller's logs, borehole video camera surveys and hole-caliper logs.

7.1.2 Well Casings

The injection well shall be cased and cemented to: (1) prevent the migration of injected fluid out of the injection zone; (2) prevent contamination of the freshwater / brackish water lens; (3) prevent the borehole from caving in; and, (4) provide a means of pressure control in

the well. There shall be two (2) casing strings: surface (outer) and injection (inner). The well shall be double-cased through the freshwater / brackish water lens, single cased through the saltwater portion of the aquifer with disposal below the Lucayan Formation.

All casing strings shall be new, free from leaks, and must be able to withstand maximum system pressures. Casing design shall allow for internal, external and collapse pressures in the system.

Both surface (outer) and injection (inner) casings shall be Polyvinyl Chloride (PVC) Well Casing which utilize a spline-lock mechanical joining system such as CertainTeed's Certa-Lok. The casing shall be made from unplasticized PVC compounds having a minimum cell

classification of 12454-B as defined in ASTM D1784-11. The compound shall qualify for a Hydrostatic Design Basis (HDB) of 4,000 psi for water at 73.4° F, in accordance with the requirements of ASTM D2837. Casing and couplings shall be homogeneous throughout and free from visible cracks, holes, foreign inclusions, blisters and dents, interior roughness, and other injurious defects that may affect wall integrity. The casing and couplings shall be as uniform as commercially practicable in color, opacity, density, and other physical characteristics.

The surface (outer) casing shall have an outside diameter of 16 inches, a SDR of 17, a minimum wall thickness of 0.941 inches, and a minimum and maximum inside diameter of 13.855 inches and 14.118 inches, respectively. The casing shall extend a minimum of 40 feet below the freshwater / brackish water lens and be grouted along the entire depth.

The injection (inner) casing shall have a nominal outside diameter of 8.625 inches, Schedule 80, and a minimum wall thickness of 0.508 inches and a minimum and maximum inside diameter of 7.458 inches and 7.609 inches, respectively. The casing shall extend a minimum of 40 feet below the confining zone in the saltwater aquifer. The casing shall be installed, and cement grouted to approximately 260 feet (+/-) below grade.

7.2 Cementing

7.2.1 Primary Cement

Cement is primarily used to prevent the migration of fluid out of the injection zone, and to bond and support the casing strings. It also provides protection of the casing from external casing degradation activities. Proper cementing is critical in providing a good seal, and adequate structural support for the well.

The cement grout shall be a mixture of cement (ASTM C-150, Type II) and not more than five (5) gallons of water per bag (1 cubic foot or 94 lbs.) of cement. Casing shall be landed as cemented.

7.2.2 Cement Additives

Cement additives can be used to improve the cement slurry characteristics once downhole conditions have been defined.

Mixtures of bentonite slurry may be used if it can be shown that the rheology of the bentonite will not be affected by addition of concrete, or that bridging, improper seal and / or movement of the

bentonite will not be a concern. The use of bentonite (up to 6% by weight of cement) must be approved prior to use.

The use of a high-solids bentonite grout shall contain at least 20% bentonite solids (by weight). The mixing ratio should not be more than 23 gallons of water per 50-lb. bag of bentonite. Use of this high-solids grout must also be approved.

Once it has been demonstrated that the base of the injection casing has been sealed within the borehole, a combination of pea gravel and ASTM C-150, Type II cement may be used to seal the annulus.

7.3 Centralizers

Centralizers shall be used on the system to assist with centering casings in the open borehole. These accessories shall meet the specifications of the American Petroleum Institute (API, 1973 or later).

7.4 Pre-injection Equipment

7.4.1 Injection Pump

The type and capacity of injection pump (if necessary) will be determined by the well-head pressure, the volume of injection fluid to be injected, and the variability of the injection rates. A well injection / pumping test(s) must be conducted to determine the overall resistance to injection; this will define the pumping design requirements.

7.4.2 Storage Tank

A storage tank shall be installed on the pre-injection system for the permeate of the wastewater treatment plant to be reused for irrigation. Final testing of injection fluid will be done as required prior to injection.

7.4.3 Instrumentation and Controls

Instrumentation shall be provided on the system to monitor flow rates, volumes, and pressures of injected water. The injection pump (if utilized) shall be shut down in a no-flow, minimum flow, or high temperature situation; an alarm will advise of this condition. The main isolation valve in the injection line may be actuated for ease of operation.

8.0 WELL CONSTRUCTION

The following guidelines address general construction issues, including sequence of drilling / setting of casings, and grouting concerns. No detailed direction is given on the construction requirements for well construction. The drilling method utilized must be capable of drilling a 24-inch diameter borehole to a depth of at least 150 feet below grade and a 16-inch diameter borehole to a depth of at least 350 feet below grade. The drilling and auxiliary equipment (if necessary) shall have sufficient fluid circulation to remove all cuttings from the borehole.

8.1 Drilling the Pilot Hole

A pilot borehole shall be drilled at the proposed site for the injection well. The borehole shall have a diameter of 8-inches and shall be drilled to the depth of surface (outer) casing anticipated to be between 100 and 150 feet (+/-) below grade.

8.1.1 A borehole video camera survey shall be undertaken and together with the driller's log and hole-caliper log shall be used to determine the final depth of the surface (outer) casing.

8.1.2 Analysis of the formation water shall demonstrate a Total Dissolved Solids concentration of at least 10,000 parts per million at the final depth of the surface (outer) casing.

8.1.3 Drilling of the pilot hole deeper than the depth of the surface (outer) casing shall cease until the surface (outer) casing has been set, cement grouted, and the grout has had sufficient time to set up (bond to the surface casing and borehole wall). This will prevent contamination of the freshwater / brackish water lens with drilling fluids and deeper formation water as the pilot hole is drilled to 350 feet (+/-).

8.2 Drilling the Surface (Outer) Casing Hole

Based on a satisfactory analysis of the driller's log, borehole video survey and hole-caliper log, the 8-inch pilot borehole shall be enlarged to a 24-inch diameter borehole. The final depth of this borehole shall be determined from the results of the driller's, borehole video log and hole caliper log.

8.3 Setting the Surface (Outer) Casing

8.3.1 The top of the surface (outer) casing (16-inch OD) shall be completed a minimum of three (3) feet above grade. The casing shall be centered in the 24-inch diameter borehole with a minimum

annular space of 3.5 inches between the borehole wall and the casing.

8.3.2 Installation of the surface (outer) casing shall be such that the casing is suspended from the top with adequate support to hold the weight of the casing. The bottom of the casing shall be a sufficient distance above the bottom of the drilled borehole and shall not be supported from below. Centralizers shall be used to keep the casing centered in the borehole during installation and cementing.

8.3.3 The PVC casing shall be joined using non-metallic couplings which, together, have been designed as an integral system for maximum reliability and interchange-ability. High-strength flexible thermoplastic splines shall be inserted into mating precision-machined grooves to provide full 360• restraint with evenly distributed loading. No external casing-to-casing restraining devices, which clamp onto or otherwise damage the casing surface as a result of point-loading shall be permitted. The joining system shall incorporate elastomeric sealing gaskets, which are designed to provide a watertight seal.

8.4 Grouting the Surface (Outer) Casing

8.4.1 Following placement of the surface (outer) casing in the open borehole, it shall be tested for plumbness and alignment. This shall be done by an approved method. The casing alignment must be satisfactory before grouting is allowed.

8.4.2 Grouting of the surface (outer) casing shall be done in a continuous operation. The base of the casing shall be pressure grouted. A packer can be placed inside the surface (outer) casing a minimum of five (5) feet above the bottom of the casing. A tremie pipe shall be used to fill the annular space between the casing and the borehole wall. Grouting shall begin at the bottom of the borehole and proceed upward. Grout return shall be verified, and the grouting process carried out continuously until the grouting is considered satisfactory.

8.4.3 During and subsequent to the grouting, formation water shall be continuously circulated and discharged within the casing for the purpose of cooling the cement grout. The source of the water will be determined by the on-site geologist / hydrogeologist depending upon the quality of the formation water encountered during the drilling of the borehole.

8.4.4 No additional drilling or work shall progress on the well until the cement grout has cured. The setting time shall be determined based on the type of grout used, the results of the circulated water temperature monitoring, and the temperature logs. Temperature logs will be run at eight (8) hour intervals during which time water circulation within the casing shall cease.

8.4.5 The grout shall be tested by an approved method and accepted. In addition to the temperature logs performed during the curing process, a final temperature log will run to confirm cure. Pressure test (maintenance of air pressure at 7-10 psi for a minimum of one (1) hour) will then be conducted.

8.5 Completing the Pilot Hole

After the cement grout seal has been placed for the surface (outer) casing, the pilot hole shall be completed to a depth of 350 feet (+/-). The driller's log, borehole video survey and hole-caliper logs shall be continued, analyzed, and a determination made on the final depth of the well.

8.6 Drilling the Injection (Inner) Casing Borehole

The injection (inner) casing borehole shall be prepared from the pilot borehole by reaming it to approximately 14 inches. The final depth of this borehole shall be determined from an analysis of the driller's log, borehole video survey and hole-caliper log.

8.7 Setting the Injection (Inner) Casing

8.7.1 The top of the injection (inner) casing (8.625-inch OD) shall be completed a minimum of three (3) feet above grade. The casing shall be centered in the 14-inch diameter borehole with a minimum annular space of 3.0 inches (+/-) between the borehole wall and the casing. The final depth of this casing string shall be determined from an analysis of the driller's and borehole video logs.

8.7.2 Installation of the injection (inner) casing shall be such that the casing is suspended from the top with adequate support to hold the weight of the casing. The bottom of the casing shall be fitted with a Schedule 80 PVC flange and tail-piece located sufficient distance above the bottom of the drilled borehole and shall not be supported from below. Centralizers shall be used to keep the casing centered in the borehole during installation and cementing.

8.7.3 The PVC casing shall be joined using non-metallic couplings which, together, have been designed as an integral system for

maximum reliability and interchangeability. The coupling may be replaced by an integral bell spline lock joint. High-strength flexible thermoplastic splines shall be inserted into mating precision-machined grooves to provide full 360• restraint with evenly distributed loading. No external casing-to-casing restraining devices which clamp onto or otherwise damage the casing surface as a result of point-loading shall be permitted. The joining system shall incorporate elastomeric sealing gaskets, which are designed to provide a watertight seal.

8.8 Grouting the Injection (Inner) Casing

Grouting of the injection (inner) casing shall be done in accordance with Sections 7.2 and 8.4. **In addition, the grouting shall be done such that no more than approximately 150 feet (+/- 10%) is grouted at any one time.**

8.9 Completing the Open Borehole

The open portion of the borehole or the injection zone shall be completed by cleaning as necessary. The extent of the injection zone shall be determined from the driller's log, borehole video survey and hole-caliper log.

8.10 Wellhead Design

The casing shall be landed as cemented. The well head shall be a flanged design with pressure gages for monitoring injection pressure.

9.0 TESTING AND DOCUMENTATION REQUIREMENTS

9.1 Testing and reporting guidelines are generally per the Technical Specification.

9.1.1 Requirements include verification of cement grout integrity by approved methods which include pressure testing (maintenance of air at 7 to 10 psi for one (1) hour), and temperature logs.

9.1.2 An acceptance test of the injection well shall be carried out in accord with the Injection Well Test Procedure set forth by the Water Resources Management Unit of the Bahamas Water and Sewage Corporation dated November 1996.

9.2 A borehole video camera survey and a hole caliper log shall be run and recorded to determine the characteristics of the formations encountered during drilling of the injection well. The analyses shall indicate the water

producing / acceptance characteristics of the formations encountered, the optimum depth of the surface (outer) and injection (inner) casing strings, the depth and extent of the injection zone, and the pumping requirements (if any). Formation water samples shall be collected, handled, and analyzed in the manner approved. Per the Technical Specification, the following information shall be included in the driller's log:

1) The reference point for all depth measurements and its elevation.
2) Depth at which each change of formation occurs
3) Identification of the material encountered during each five (5) foot interval of drilling and/or change of formation.
4) Rate of drill bit penetration including note of any drop
5) Pressure on drill bit
6) Fluid circulation pressure, and
7) Any other pertinent data requested.

9.3 A report shall be prepared and submitted to include the following information:

1) All driller's logs, borehole video surveys and hole caliper logs made during the course of well drilling and well construction;
2) Total depth of the completed injection well including the extent of the open borehole injection zone;
3) Depth and location of the loss of any drilling fluid, drilling materials, and/or drilling tools and equipment;
4) Annulus volume calculations for each borehole and casing string and the actual volume of cement grout placed;
5) Depth and description of each casing string;
6) Description and results of the injection test; and,
7) Other pertinent data.

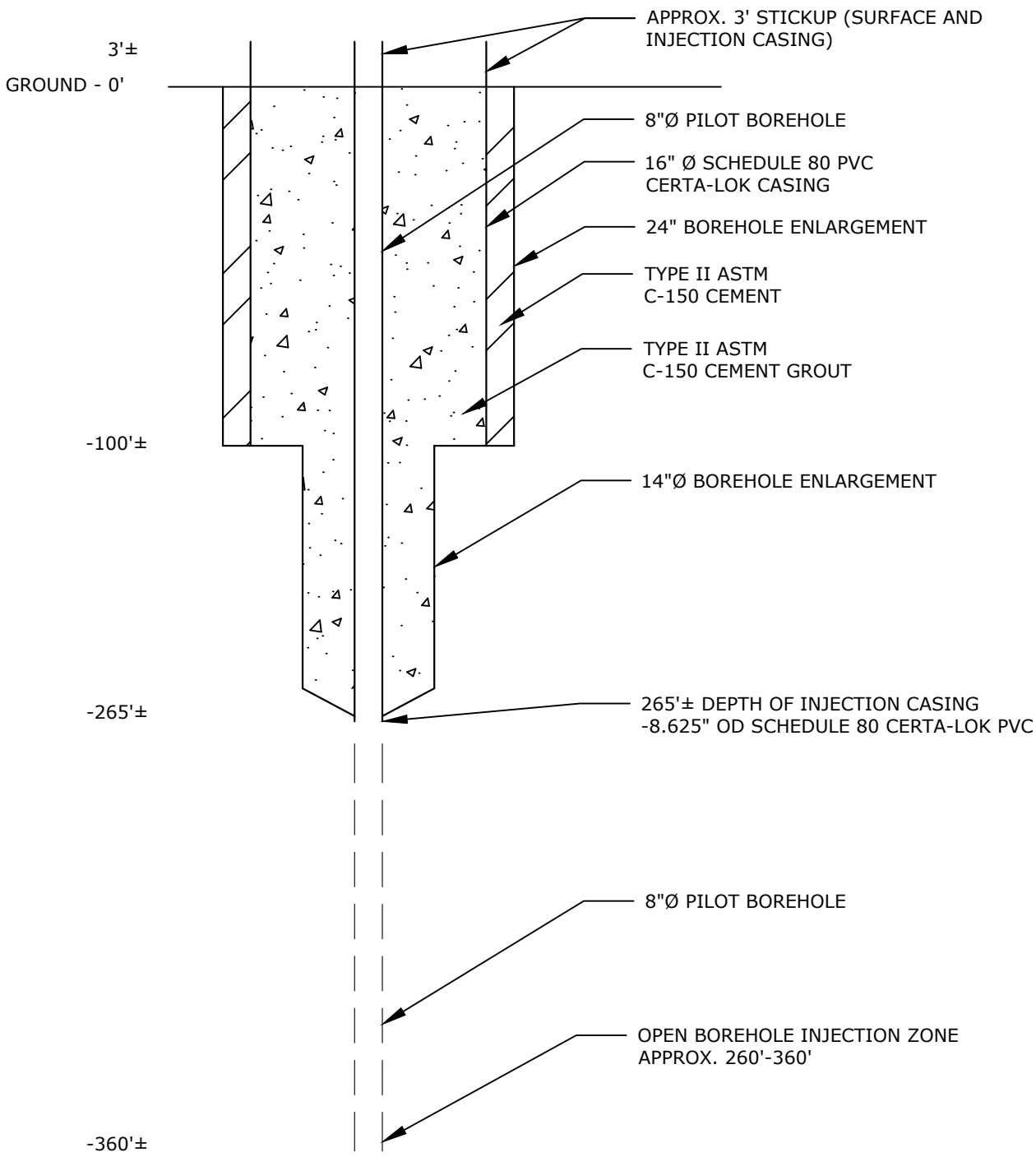

FIGURE _
TYPICAL INJECTION WELL

CARNIVAL GRAND PORT
GRAND BAHAMA ISLAND - SHARP ROCKS POINT
COMMONWEALTH OF THE BAHAMAS

R.C. MINNING & ASSOCIATES.