NIGERIAN INDUSTRIAL STANDARD

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Code of Practice for Water Well Construction

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Approved by SON Governing Council

STANDARDS ORGANISATION OF NIGERIA

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Foreword

This Nigerian Code of Practice for Well Construction was elaborated by the Technical Committee for Water Well Construction

Groundwater development is one of the sources of the Federal and State Governments Water Supply Intervention Programmes under which government embarked on construction of open wells and boreholes in order to increase access to portable water to Nigerians. However, water well construction is still characterized by cases of “failed hole”, poor quality service, and unprofessional conduct of drillers and lack of established code to regulate the practice of water well drilling in Nigeria. These are serious concern to government, donor agencies and sector stakeholders who see them as militating factors towards attainment of water supply project objectives in particular and Millennium Development Goals (MDGs) in general. This Code of Practice was therefore elaborated to provide the framework for water well construction in Nigeria.

In the elaboration of this Code of Practice, reference made to Nigerian Industrial standards and National standards of other countries are hereby acknowledged.

1. Scope

This Nigerian Code of Practice specifies the minimum requirements for drillers, supervising personnel and equipment to ensure cost effective water well construction and sustainable groundwater resources development in Nigeria.

It also specifies the procedures governing the location, construction, maintenance and abandonment of water well, and the installation of pumps and pumping equipment; to conserve and protect the groundwater resources of the nation against contamination and to ensure safety of all water well construction activities.

The code is applicable to all wells to be constructed, rehabilitated or abandoned, regardless of depth, for public and private water consumption in the Federal Republic of Nigeria.

2. Normative References

(i) ASTM A120-84 - Specification for Pipe, Steel, Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless for Ordinary Uses
(ii) ASTM A53/A53M - 07 - Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
(iii) ASTM A589-96 Standard Specification for Seamless and Welded Carbon Steel Water-Well Pipe
(iv) ASTM A530/ASME SA530 standard specification for general requirements for specialized carbon and alloy steel pipe (ASTM A 530 / ASME SA 530 /ASTMA530/ASMESA530).
(v) ASTM F480 - 06b Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), SCH 40 and SCH 80.
(vi) ASTM F480-06a Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), SCH 40 and SCH 80.
(vii) ASTM C688 - 08 Standard Specifications for Functional Additions for Use in Hydraulic Cements
(viii) NIS 554: 2007 – Nigerian Industrial Standard for Drinking Water Quality
(ix) NIS 444 – 1: 2003 –Nigerian Industrial Standard for Cement – Part 1: Composition, Specifications and Conformity Criteria for Common Cements

3. Terminology

For the purpose of this code of practice, the following definitions and terms shall apply:

3.1 **Abandoned Well (also Decommissioned Well)** – A well which has been permanently removed from service by filling and/or plugging in accordance with this code.

3.2 **Annular Space** - The space between two (2) concentric cylindrical objects, one of which surrounds the other, such as the space between the walls of a drilled hole (well bore) and a casing or between a temporary surface casing and a permanent casing.

3.3 **Aquifer** - Any geologic formation that will yield water to a well in sufficient quantities to make the production of water from this formation feasible for beneficial use.

3.4 **Artesian Well -** any well that derives its water from a confined aquifer under pressure so that the water will rise in the well casing or drilled hole above the elevation where it was first encountered. This term includes flowing wells and wells with water that do not flow freely.

3.5 **ASTM** - American Society for Testing of Materials.

3.6 **Bore Diameter** - the diameter of the hole in the formation made by the drill bit.

3.7 **Bedrock** - any rock that is not weathered or fractured.

3.8 **Bentonite -** a type of clay used during Well construction, or plugging of well.

3.9 **Casing -** an impervious durable pipe placed in a well to prevent the walls from caving and to help seal off surface drainage or undesirable water, gas or other fluids from entering the well.

3.10 **Well Completion Report** - a certified report on a completed well specifying location, name of well owner, static water level, yield, total depth, Well size, casing size, screen interval and other hydraulic properties.

3.11 **Certification -** a recognition given by approved authorities under this code to professional individuals or corporate bodies. Certification is a testament of a consultant's proven competence and self discipline expected of a professional to pursue a broad competence base both technically and ethically.

3.12 **Chlorine -** is an oxidizing disinfectant that kills bacteria on contact.

3.13 **Consolidated Formations** - geologic formations that have been compacted.

3.14 **Construction** - acts necessary to the actual drilling and completion of a well as defined in this code, but excluding the installation of surface appurtenances such as pumps and pumping equipment.

3.15 **Contamination** - the presence of any foreign substance (organic, inorganic or radiological) in water which tends to degrade its quality so as to constitute a hazard or impair the usefulness of the water.

3.16 **Cuttings-** the geologic material displaced from the drill hole during drilling.

3.17 **Driller's certificate-** an official document issued by NWRI to any person after successfully undergoing a prescribed course of study in well drilling at NWRI or elsewhere.

3.18 **Driller** - the licensed operator of a drilling rig as authorized under this code.

3.19 **Drilling** - the act of constructing or modifying a well.

3.20 **Drilling Rig** - any power driven percussion, rotary, boring, digging, jetting, or auguring machine used in the construction or modification of a well.

3.21 **Drive shoe** - the fitting placed at the bottom of the permanent metal casing, which enables the driller to efficiently drive the casing into solid rock.

3.22 **Examination** - assessment of professional competency administered to applicants.

3.23 **Fill** - placing of suitable materials in the well bore of an abandoned well for the effective and permanent prevention of the vertical movement of water within the well bore, including vertical movement of water within the annular space surrounding well casing.

3.24 **Gravel Pack** - The placement of gravel or other permeable material (artificial or natural) in the annular space around a perforated well casing or well screen.

3.25 **Groundwater** - water found in the subsurface in the saturated zone below the water table.

3.26 **Grout** – a mixture of cement or bentonite and potable water.

3.27 **IPAN-** Institute of Professional Analyst of Nigeria

3.28 **License-** authorization issued by the NWRI authorizing any person or corporate body to undertake well drilling within Nigeria.

3.29 **Lithologic log** - a description of observable physical characteristics of all rock types encountered during drilling of well.

3.30 **L.G.A -** Local Government Area

3.31 **Modify (Major reconstruction)** - the alteration or repair of any well that changes the original specifications or casing depths or total depth of the well; for example: liners, packers or deepening of well or extension of casing above finished level.

3.32 **Monitoring Well** - wells used for the purpose of observing subsurface hydrologic conditions and collecting hydrologic or water quality data and not for use in extracting water from an aquifer for beneficial use.

3.33 **NWRI** - National Water Resources Institute, Kaduna.

3.34 **Owner** - the owner of the land on which the well is located unless a deed, covenant, contract, easement, or other documentation demonstrates that the well is the responsibility of another party.

3.35 **Permit** - a well drilling authorization or well operating permit issued by appropriate authority recognized by this code.

3.36 **Plastic Pipe** - thermoplastic pipe or casing material composed of either polyvinyl chloride (PVC) or acrylonitrile-butadiene-styrene (ABS).

3.37 **Plug** - placing of sealing materials (lead wool, steel shavings or large stones of not more than 1/3 of the diameter of the hole) in the bore of an abandoned well.

3.38 **Potable water** - water which meets the specifications provided in NIS 554: 2007.

3.39 **Pressure grouting** - the process of applying grout material under pressure to the annular space of a well for the purpose of sealing it and thus preventing vertical movement of fluids through the annular space. Grout must be introduced from the bottom of the annular space.

3.40 **Pumps and pumping equipment -** machines used or intended for use in withdrawing or obtaining groundwater for any use.

3.41 **Screen** - a pipe with perforations or slots that allows water to enter into a well and at the same time prevent undesirable particles from entering the well.

3.42 **Septic tank** - a watertight tank of durable materials through which sewage flows very slowly and in which solids separate from liquid to be decomposed or broken down by bacterial action.

3.43 **Sewage -** means spent water carried from residences, commercial and industrial buildings.

3.44 **Site -** a location on which a well is drilled or to be drilled.

3.45 **SON** - Standards Organisation of Nigeria.

3.46 **Static Water Level** - the distance measured from the established ground level to the water level in a well neither being pumped, nor under the influence of neither pumping nor flowing under artesian pressure.

3.47 **Tremie pipe** a small diameter conductor pipe, hose or tubing used in the down-hole placement of well construction material.

3.48 **Unconsolidated Formation** - A naturally-occurring earth formation that has not been compacted e.g. gravel, sand and clay.

3.49 **U.T.M** – Universal Transverse Mercator

3.50 **Wellhead Protection Area** - the surface and subsurface area surrounding a water well or wellfield supplying a public water system through which contaminants are likely to move toward and reach such water well or wellfield,

3.51 **Well** - any hole that is driven, drilled, dug, or bored, either cased or uncased, by any method into the ground, for the purpose of obtaining water or knowledge of water bearing or soil formations, or for the disposal of surface water drainage.

3.52 **Well Cover** - a device or method used to protect a well casing or water system from the entrance of any external pollutant at the point of entrance into the casing.

3.53 **Well Development** - the act of bailing, jetting, pumping, or surging water in a well to remove drilling fluids, fines, and suspended materials from within the well, screen, filter pack, and aquifer to establish the optimal hydraulic connection between the well and the aquifer.

3.54 **Well vent** - an outlet at the upper terminal of a well casing to allow equalization of air pressure in the well and to measure water level inside the well.

3.55 **Yield** - the quantity of water per unit of time that may flow or be pumped from a well under specified conditions.

4. Legal Requirements

4.1 For the purpose of constructing water wells in Nigeria, the following requirements shall apply.

(a) Possession of a Well Drilling License by a drilling company/individual.
(b) Permits shall be obtained for water well construction.
(c) Well completion reports shall be certified by registered practitioners and deposited in the office of the Minister responsible for Water Resources
(d) Authentication of water well completion report shall be the responsibility of hydrogeologists registered by COMEG.
(e) Authentication of water quality analysis report shall be the responsibility of duly registered analyst from an accredited laboratory.

4.2 Drilling Permit

No water well shall be constructed unless the owner is in possession of a valid permit to do so. A drilling permit shall authorize the construction of one or multiple wells in specified location(s) in compliance with the conditions of approval specified for that purpose.

Permit shall be given by Agency designated by the Minister in charge of Water Resources.

4.2.1 Application for Drilling Permit.

An application for drilling permit shall be completed in the specified form as shown in **Appendix A**

4.2.2 Denial of Permit Application

An application for permit shall be denied for any of the following reasons:

(a) False or misleading information contained in the application form;
(b) Failure of the applicant to submit the application with the appropriate fee;
(c) Noncompliance with other requirements of this code;
(d) Any other lawful ground stated by the Approving Agency.

4.3 Water Well Driller's License

(a) Water well driller's license shall be obtained from NWRI on application.
(b) No person shall construct a well for the abstraction or monitoring of groundwater or for research if that person does not have a driller's license granted in accordance with the provisions of this code. The requirements of a driller's license shall be applicable to any person, company, corporation, or other entity engaged in the business or occupation that involves construction of water wells that may penetrate water bearing

(c) strata (including constructing water wells, geo-thermal systems and environmental monitoring wells).

4.3.1 Application for Drilling License

An applicant for a water well driller's license, as defined in this code, shall obtain and submit a prescribed application form as shown in Appendix B, and meet with the requirements set forth below:

4.3.1.1 In the Case of an Individual

(a) Be at least twenty (21) years of age;
(b) Pass a prescribed examination conducted by NWRI;
(c) Give a written undertaking that he / she shall only engage in the practice for which the license is granted;
(d) Provide evidence of at least three (3) years post qualification experience i.e. experiences gained while working under the direct supervision of a licensee engaged in the business or practice for which the license is being sought.

Where before the coming into force of this code, an individual who has attained the age of thirty (30) years and has been engaged in water well construction for not less than five (5) years, if not previously certified to construct, shall provide evidence of cognate experience and skills acceptable to NWRI, which shall include passing a general aptitude test (this exemption provision shall remain in force for five (5) years from the date of commencement of this code and shall thereafter cease to operate).

4.3.1.2 In the Case of Corporate Bodies

(a) Shall be duly incorporated in Nigeria under the Companies and Allied Matters Act (CAMA), to carry on the business of water well drilling;
(b) Shall show evidence of at least one (1) licensed driller, and one (1) registered hydrogeologist and one (1) registered water resources engineer in its employment;
(c) Shall show evidence of available functional drilling rig and other equipment, indicating:

(i) The description;
(ii) The trade mark;
(iii) Age; and
(iv) Operational Status (i.e. □Fairly Good, □Good or □Very Good).

(d) Shall show evidence of drilling activities conducted during the five years immediately preceding the application, indicating:

(i) Client Name, address and phone number;
(ii) the year the activities were undertaken; and
(iii) the location(s) where the activities took place.

However, in the case of a new company, it shall show evidence that the staff required under provisions of subclause 4.3.1.2 of paragraph (b) above have attained the level of experience specified in subclause 4.3.1.2 subclause (d) above.

(e) Any other relevant information required.

4.3.2 License Fee

An applicant who qualifies for a license shall pay a prescribed license fee as specified by the issuing Authority (NWRI or any other body authorized by this code).

4.3.3 License Renewal

(a) A drilling license shall remain valid for a period of five (5) years, and may be renewed.
(b) An application for the renewal of the license shall be made to NWRI not later than thirty (30) days before the expiration of the license.
(c) The renewal shall attract the fee specified by NWRI. Late renewal shall attract additional fee as specified by NWRI.
(d) A licensee shall request that an expired license be re-instated by submitting to NWRI the required renewal form and paying the appropriate fee plus accumulated late fees. Failure to request re-instatement within two (2) years after the expiration date shall be deemed a forfeiture of the reinstatement option. Any request for reinstatement submitted thereafter shall require submission of a new application and be subject to the examination requirements.

4.3.4 Process of Application

NWRI shall:

(a) acknowledge receipt of the application within twenty one (21) days of receipt of the application for a drilling license, and
(b) inform the applicant in writing of the decision of NWRI within sixty (60) days after the receipt of the application.

Where

(i) an applicant fails to pay the prescribed processing fee or,
(ii) there is an error in the application,

NWRI shall notify the applicant in writing within twenty one (21) days after the receipt of the application to rectify the situation.

4.3.5 Denial of Water Well Driller's License

An application for water well driller's license shall be denied for any of the following reasons:

(a) False or misleading information contained in the application form;
(b) Failure of the applicant to submit the application with the appropriate processing fee;
(c) Noncompliance with other requirements of this code.

4.3.6 Register of Drillers License

(a) NWRI shall maintain a register containing the particulars of licensed drillers, licenses granted and the register shall be accessible to the public.
(b) Extracts from the register may be obtained from NWRI on request and on payment of a fee.

4.3.7 Penalties and Appeals

Any person who violates any of the provisions of this code shall be penalized in accordance with the provisions related to breach of grant of license under Rules made pursuant to this code.

Any order or decision of NWRI shall be appealable under Rules made pursuant to this code.

4.3.8 Requirements for Water Well Drilling Consultants

All Consultants (Corporate or Individuals) engaged in water well drilling consultancy shall register with professional bodies in Nigeria (COMEG and COREN) and be documented with NWRI;

NWRI shall maintain a register containing the particulars of qualified Consultants and the register shall be accessible to the public.

5. Technical Requirements

5.1 Well Construction Requirements

The Well Driller shall construct each well:

(a) In accordance with the provisions of this code and in addition to any conditions attached to the grant of permit and license, and in a manner that will protect the groundwater resources.

(b) Based on the geologic and groundwater conditions known to exist as specified in the hydrogeological / geophysical report. This report gives detail of the geophysical investigation of the proposed water well site. The investigation shall entail geological/hydrogeological mapping and geophysical survey using resistivity and or electromagnetic method carried out by registered Geoscientist.

(c) Such that it is capable of producing, where obtainable, the quantity of water to support uses by the well owner, subject to this code;

(d) Such that it complies with the sitting distance requirements specified in Table 1.

Table 1 - Minimum Sitting Distance Requirements for Well

Separation of Well from	Minimum Separation Distance (m)
Water Supply boreholes	50
Hand dug water wells	20
Septic drain field	35
Septic tank	20
Drain field of system with more than 10,000L/day of sewage inflow	100
Permanent buildings or structures	3
Livestock Pen	75
Streams, canals, irrigation ditches or laterals, and other permanent, temporary, or intermittent bodies of water	20
Approved Solid waste dump including burial ground	1000
Coastline	1000

(e) Such that wells are located up gradient (uphill) of nearby potential sources of pollution (i.e., the land shall NOT slope from pollution sources towards water wells).

5.2 Compliance with the above siting and separation distances does not exempt the driller from complying with other requirements established by Local Government Health Departments, National Environmental Standards and Regulation

Enforcement Agency (NESREA), other authorized bodies and hydrogeological peculiarity of the terrain.

5.3 Drilling

5.3.1 Selection of Drilling Method

The well shall be drilled using any of the following methods with due consideration to hydrogeologic/geophysical report. The primary drilling methods for Water Wells employed in the Nigeria shall include Rotary air percussion; Cable tool (percussion); Mud Rotary Drilling; Jetting; Manual drilling; and Driving (well points).

5.3.2 Drilling Equipment

The Driller shall provide functional and standardized drilling equipment required for the drilling of the well. The following basic drilling equipment applies (rig, compressor, mud pump and drilling accessories) as may be dictated by the method of drilling selected.

5.3.3 Plumbness and Alignment

(a) The driller shall ensure that throughout the drilling, the hole is plumbed and properly aligned.
(b) Test for any obstruction, plumbness and alignment shall be carried out after completion and before its acceptance.
(c) A well shall not vary in vertical alignment so as to interfere with installation and operation of the pump.
(d) If the well is not straight, plumb and free of any obstruction, as specified, the well shall be straightened, plumbed and freed of all obstructions or a new well shall be drilled at no additional cost to the owner. The abandoned hole shall be filled in accordance with the requirements of subclause 5.17 of this code.

5.3.4 Sample Logging and Record Keeping

(a) The driller shall keep all record of drilling activities and complete Appendices E and F using G for each well.

(e) Samples shall be taken by the driller at one (1) metre intervals in both sedimentary and basement rock formations.
(f) The samples shall be laid out in a neat and orderly fashion at the drilling site.
(g) The samples shall be set out in a sample box and labeled.

5.3.5 Basic Drilling Data

In addition to any reporting required by the contract document or owner/supervisor, the Water Well Driller shall keep the daily records while drilling activities are underway and complete Appendix A4 for each well.

5.3.6 Drilling Fluid

Only clean water shall be used in the make-up of drilling fluids whether employed alone or in combination with drilling additives. Only high grade clays or commercial chemicals that meet the requirements of Nigerian Industrial Standards shall be used in the make-up of any drilling fluid. Drilling fluid with a mixture of water and unprocessed mud, clay, or other material shall not be permitted. Drilling fluid shall not impart any toxic substances to the water or promote bacterial contamination. Drilling fluid ejected from the well during drilling operation must be contained on-site or disposed off in a way not to contaminate groundwater.

When and only if it becomes necessary to add clays or chemicals to the drilling fluid, it must be borne in mind that it is desirable to maintain a mud system containing a minimum of clay and fine sand and to obtain representative lithologic samples and minimize sealing of well with mudcake or mud invasion into formation. If there should be a conflict between the mud requirements for ease in drilling and the mud requirements for sample attainment and minimal sealing; then the ruling requirements shall be those for sample attainment and minimal sealing.

The driller shall be responsible for maintaining the quality of the drilling fluid to assure;

(i) Protection of water bearing and potential water bearing formations exposed in the Water Well and
(ii) Good representative samples of the formation material.

5.4 Well Geophysical Logging

Geophysical logging shall be undertaken to aid well design for boreholes deeper than 100m.

Each logging device must be capable of producing a continuous simultaneous strip record of spontaneous potential and resistivity and separately a continuous strip record of gamma radiation.

5.5 Typical Water Well Designs

Although Water Well design is site specific and it is impossible to describe every type of possible Water Well design that may be utilized in any part of the country, a summary of the most prevalent types is provided below as a guide.

5.5.1 Type 1 Design - Complete Lining and Plug at the Bottom

This type of design is common where overlying or aquifer formations are unstable. In addition to the sanitary seal, an assembly with a screened interval

set adjacent to the primary aquifer horizon is installed in the Water Well. Gravel pack (formation stabilizer) is installed surrounding the screens, with the upper section of the annular space backfilled or grouted. Centralizers are installed above and below the screen and at intervals to the surface.

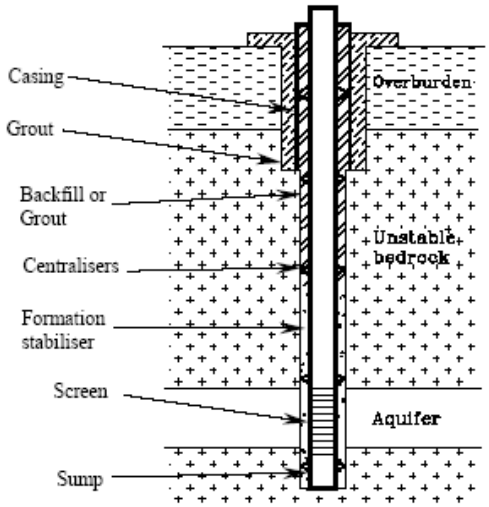

Figure 1 - Type 1 Design

5.5.2 Type 2 Design - Filter Packed Water Well in Unconsolidated Formation

In unconsolidated formations (i.e. coastal plain sediments, river alluvium), Water Wells must be screened. This design is for an aquifer where the grain size and grading is such that filter packing is required. After a surface casing is installed and grouted, drilling is completed through the targeted aquifer horizon. An assembly with screens and centralizers is lowered into the Water Well and properly sized and graded filter pack installed surrounding the screen(s). The remaining annular space is backfilled or grouted.

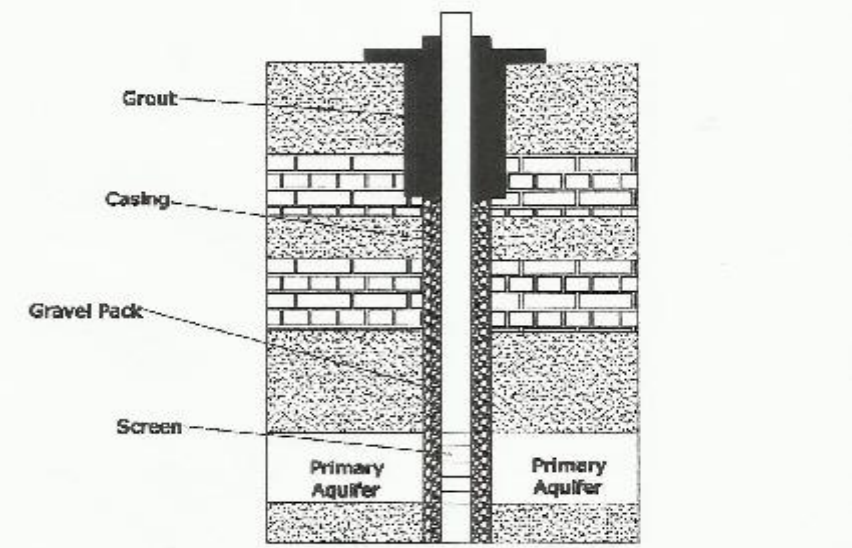

Figure 2 - Type 2 Design (Modify diagram to show gravel)

5.5.3 Type 3 Design - Telescopic Water Well Design

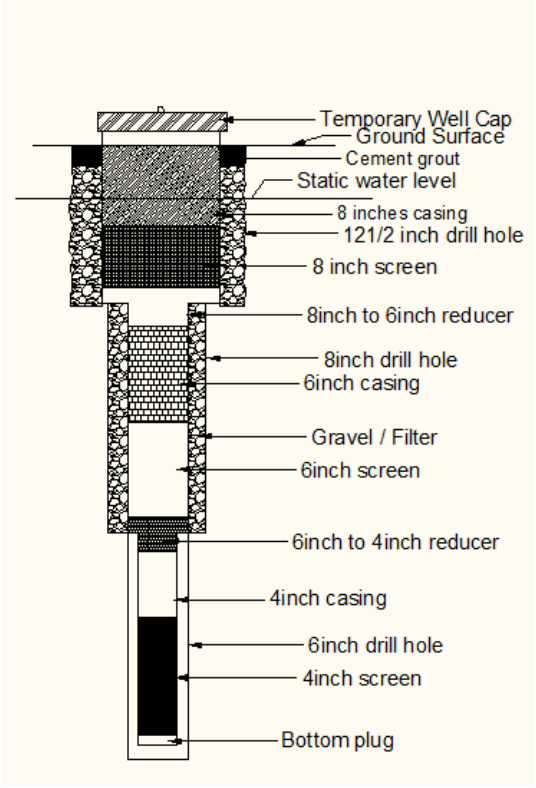

Figure 3 - Type 3 Design (Telescopic borehole design

5.6. Casing

Casings shall either be bitumen coated steel, unplastized Polyvinyl Chloride (uPVC) or other appropriate materials.

(a) In constructing any well, all water-bearing zones that are known to contain polluted, saline, or other non-potable water shall be adequately cased and cemented off so that pollution of overlying and underlying groundwater zones shall not occur.
(b) The casing in wells sunk in consolidated rock formations shall be adequate to prevent any formational material from entering.
(c) The casing in wells sunk into unconsolidated rock formations (such as gravel, sand or shale) shall extend at least 300mm into the water-bearing formation.
(d) Upon completion of the well, the well shall be sufficiently free of obstacles including formation materials to allow for the installation and proper operation of pumps and associated equipment.

5.6.1 Steel Casing

For water well deeper than 100m, bitumen coated steel casing of the underlisted specification shall be used:

(a) The casing shall be new, seamless or electric-resistance welded galvanized or black steel pipe. Galvanizing shall be done in accordance with requirements of ASTM A-120;
(b) The casing, threads and couplings shall meet the specifications of ASTM A-53, A-120 or A589;
(c) The minimum wall thickness for a given diameter shall be as specified in Table 2.

Table 2 - Minimum Wall Thickness for Steel Casing

Nominal Diameter (mm)	Wall Thickness (mm)
100	3.607
125	3.962
138	4.166
150	4.7
200	6.35
250	7.087
300	8.382
350 and larger	9.525

(d) Stainless steel casing, threads, and couplings shall conform in specifications to the general requirements in ASTM A-530 and also shall conform to the specific requirements in the ASTM standard that best describes the chemical makeup of the stainless steel casing that is intended for use in the construction of the well;
(e) Stainless steel casing shall have a minimum wall thickness that is equivalent to ISO standard; and

(f) Steel casing shall be equipped with a drive shoe if the casing is driven in a consolidated rock formation. The drive shoe shall be made of forged, high carbon, tempered seamless steel and shall have a beveled, hardened cement or concrete grout surrounds and extends the entire length of the casing.

5.6.2 UPVC Casing

For water well less than 100m deep, uPVC casing of the underlisted specification shall be used:

(a) the casing shall be new;
(b) the casing and joints shall meet or exceed all the specifications of ASTM F-480-81, except that the outside diameters shall not be restricted to those listed in F-480; and
(c) The top of the casing shall be terminated by the driller at 300mm protruded above ground surface.
(d) For wells in which the casing will extend into consolidated rock, thermoplastic casing shall be equipped with a coupling, or other device approved by the manufacturer of the casing, that is sufficient to protect the physical integrity of the uPVC casing during the processes of seating and grouting the casing and subsequent drilling operations.
(e) uPVC casing shall not be driven into consolidated rock.

5.6.3 Other Casings

(a) Other Casing pipe that is manufactured from thermoplastic materials other than PVC shall be new pipe that contains a label or imprint indicating compliance with ASTM specification F 480 and standards for use with drinking water. The Casing and joints must be of sufficient strength and construction to ensure that integrity, shape, and ability to properly function are maintained during and after installation.

5.7 Screens

(a) All water well shall be screened adequately to allow free flow of water and prevent the entrance of soil or formation material into the well. The choice of the type and placement of screens shall be based on evaluation of all available information on the aquifer unit.
(b) The well screen shall:

(i) Be of steel, stainless steel or uPVC material and shall be of a strength to satisfactorily withstand chemical and physical forces applied to it during and after installation;
(ii) Be of a design to permit optimum development of the aquifer with minimum head loss consistent with the intended use of the well;

(iii) Have openings designed to prevent clogging and shall be free of rough edges, irregularities or other defects that may accelerate or contribute to corrosion or clogging; and

(iv) Be provided with such fittings as are necessary to seal the top of the screen to the watertight casing and to close the bottom. If the screen is installed through the casing, a packer, seal or other approved design shall be used to prevent the entry of groundwater into the well through any openings other than the screen.

(c) Multi-screened wells shall not connect aquifers or zones which have differences in:

(i) Water quality to the extent that intermixing of the waters would result in deterioration of the water quality in any aquifer or zone.

(ii) Static water levels that would result in depletion of water from any aquifer or zone, or significant loss of head in any aquifer or zone.

The conventional screen types and designs available for driller's considerations are summarized in Table 3.

Table 3 - Types of Screen

Screen Type	Design	Applications
Slotted	Slots cut horizontally or vertically in casing	Primarily consolidated formations
Louvered and Bridge Slot	Openings are mechanically punched into steel which forces a lip of steel outwards	Primarily consolidated formations
Continuous Slot Screen (wedge wire)	Wedge shaped wire wrapped around longitudinal supports	Primarily unconsolidated formations
Composite	Screens with filter packing material integrated.	Primarily unconsolidated formations
Well points	May be continuous slot type, slotted or wire gauze covered openings	Unconsolidated formations

5.8 Gravel-Packed Wells

5.8.1 Gravel used in gravel-packed wells shall come from clean sources and shall be thoroughly sieved, washed and disinfected before being placed in the well. Under no circumstances shall crushed rock and/or laterite be used as gravel pack material.

The gravel to be installed:

(a) shall be composed of sound medium to coarse sand and gravel which shall be clean, well-rounded (gravel), uniform, water-washed and free from clay, silt, organic matter, gypsum, iron, manganese or other deleterious materials.
(b) Shall be selected by the Driller with the Site supervisor's approval based on formation analysis. Material shall have an average specific gravity of not less than 2.5 and a uniformity coefficient not greater than 2.0. Gradation shall conform to that required to retain the 60th percentile of the finest aquifer material encountered in the zone(s) where screens are to be placed. A certificate of quality and gradation of the gravel from an approved testing laboratory shall be submitted to the site supervisor prior to gravel being delivered to the site. The site supervisor may elect to have a certified testing laboratory perform an independent sieve analysis to verify conformity with submitted sample. Failure of the submitted sample to meet gradation requirements shall be grounds for rejection.
(c) The gravel shall be placed in the annular space around the screens and casing by any method that will insure accurate placement and avoid bridging or segregation.
(d) The gravel pack shall have a minimum thickness of at least 25mm and shall be placed at a minimum of five (5) metres below ground surface.
(e) The gravel shall be disinfected using water with a free chlorine residual of at least 50ppm.

The gravel pack shall not connect aquifers or zones which have differences:

(a) In water quality that would result in deterioration of the water quality in any aquifer or zone.
(b) In static water levels that would result in depletion of water from any aquifer or significant loss of head in any aquifer or zone.

5.8.2 Gravel Pack Design

To ensure the optimal efficiency of a Water Well completed in unconsolidated sand aquifers which requires a filter pack as well as to avoid sand pumping during the life of the Water Well, the Driller shall ensure that proper filter pack design methods are followed. A common method is described in Appendix Q.

5.9 Water Well Development

(a) Every well shall be developed, using any of the methods identified in Table 4 below, to remove the natural silts and clays, drill cuttings, or other foreign matter from the well that would render the well useless for its intended purpose;
(b) Development shall continue until the water from the well is clean and silt-free.

(c) Developing, redeveloping, or conditioning of a well shall be done with care and by methods which will not cause damage to the well or its casing or cause adverse sub-surface conditions that may destroy barriers to the vertical movement of water between aquifers.

(d) Where chemical conditioning is required, the specifications shall include provisions for the method, equipment, chemicals, testing for residual chemicals, and disposal of waste and inhibitors.

5.10 Grouting

(a) The annulus of the Well shall be grouted to a minimum depth of five metres (5m) in basement and ten metres (10m) in the sedimentary formations below ground surface and as necessary to seal off, from the producing zone(s), all aquifers or zones with water containing organic or other contaminants of such type and quantity as to render water from those aquifers or zones unsafe or harmful or unsuitable for human consumption and general use.

(b) Grout shall be placed around the casing by using any one or combinations of the following methods:

(i) Gravity - Grout shall be placed in the annular space by gravity flow in such a manner that ensure complete filling of the space to a maximum depth as specified in subclause 5.10 (a),

(ii) Pressure - Grout shall be pumped or forced under pressure through the bottom of the casing until it fills the annular area around the casing and overflows at the surface; or

(iii) Pumping - Grout shall be pumped into place through a hose or pipe extended to the bottom of the annular space which can be raised as the grout is applied. The grout hose or pipe shall remain submerged in grout during the entire application.

(c) If an outer casing is installed, it shall be grouted by either the pumping or pressure method.

(d) The liquid and solid components of all grout mixtures shall be thoroughly blended prior to placement below ground surface.

(e) The well shall be grouted immediately after well development.

(f) No additives which will accelerate the process of hydration shall be used in grout for uPVC well casing.

(g) Where grouting is required by the provisions of this Section, the grout shall extend outward from the casing wall to a minimum thickness equal to either one-third of the diameter of the outside dimension of the casing or 50mm.

Table 4 - Water Well Development Methods and their Applicability

Method	Rig or Equipment required	Comments
Blowing	Air compressor	Most common particularly for handpump Water Wells, effective in a variety of environments
Bailing	Cable tool, bailer	Also common for handpump Water Wells
Air lift pumping	Any rig with air compressor; appropriate air lift piping	Similar to blowing, can be more effective in very porous aquifers and large diameter Water Wells
Pumping	Any rig (including jetting, manual drilling) with pump	Can be used by jetting rigs or for manually drilled wells, by a power or hand operated pump
Backwashing, air surging	Any rig with air compressor or Water Well pump	Creates surging action without requiring surge blocks or special tools
Air lift pumping /Surging	Any rig with air compressor, air lift equipment with valve	Effective for Water Wells in sandstone aquifers
Surging	Cable tool or rotary rig, surge block	Not recommended for aquifers with clay layers
Surging/Air lift Pumping	Cable tool rig, air compressor, isolation tool	Very effective in unconsolidated aquifers; only for screened Water Wells
Jetting (air)	Rotary, air compressor, jetting tool.	Best with wire wrap screens; only for screened Water Wells

5.10.1 Approved Grouting Materials

(a) **Neat Cement Grout**. This grout shall be a mixture of one bag, 50kg of Portland cement (NIS 444 – 1: 2003) to not more than 25litres of clean water. The use of bentonite, up to six percent by weight of cement to reduce shrinkage or other additives (ASTM C688) to reduce permeability, increase fluidity and / or control time of set or both, must be approved by the Engineer.

(b) **Bentonite Grout**. When grouting annular spaces with non-slurry bentonite, great care must be exercised to ensure the bentonite is placed properly. Flash swelling may occur and bridge off the annular space preventing an adequate seal. Therefore, only bentonite specifically designed to prevent flash hydration and to fall through standing water shall be used.

(c) **Sand Cement Grout.** This grout shall be a mixture of Portland cement and sand in the ratio of 1:3.

(d) **Clay grout.** This grout shall be a mixture of bentonite with the minimum amount of clean water required to facilitate placement.

5.11 Pumping Test

Pumping test shall be carried out using all necessary equipment and materials after the well development. The pumping test shall be conducted to:

(a) Determine well and aquifer parameters (Static and dynamic water levels, yield, drawdown, transmissivity, storativity, specific capacity, recovery rate).

(b) Determine pumping regime (pump capacity, depth of installation) and

(c) Obtain samples for field based water quality parameters (pH, temperature, EC, TDS, bi-carbonate).

5.11.1 Equipment and materials for pumping test shall include:

(a) Appropriate submersible pump and accessories.

(b) Power source.

(c) Dip meter.

(d) Flow measuring device (flow meter, graduated container of known volume, stop watch and others).

5.11.2 Reading and recording of pump discharge shall be made by the hydrogeologist at intervals as specified in this code. Measurement of time of start, stop and interval measurements must be made with reasonable accuracy (±5 seconds). Any irregular events (e.g. pump failure and restart occurring during the test cycle must be noted and their times recorded. If the pumping test is interrupted by any of these circumstances, the test shall be rerun. Pumping rate (Q) shall not vary by more than 5%. No pumping of the production well to be tested shall occur until it recovers to the static water level. The time interval between water-level measurements may vary between acceptable limits as indicated in Table 5 below. The data generated from pumping tests shall be included in the Water Well completion report.

Table 5 - Time Interval between Water Level Measurements during Pumping Test

Time after start or stop of new discharge step (minutes)	Recommended measuring interval (minutes)
1-10	1
10-20	2
20-30	5
30-60	10
60-120	15
120-300	30
300 to end of test	60

5.11.3 Types of Pumping Test

(i) Step-Drawdown Test

The **hydrogeologist/water resources engineer** shall conduct a step-drawdown test of the well by pumping at a sufficient number of rates (at least 3) to determine the shape of the drawdown curve to the maximum capacity of the well. Pumping shall continue at each rate for a sufficient length of time to bring about a stable (or predictable) water level trend in the well (i.e. a semi-logarithmic plot of pumping level versus time shows a straight-line trend). The step-drawdown data shall be sufficient such that the following results are obtained:

(a) Well efficiency diagram for the range of discharges tested.
(b) Specific Capacity and Transmissivity diagram showing formation and well loss curves for the range of discharges tested.
(c) Recommended pumping regime based on aquifer characteristics.
(d) The hydrogeologist / water resources engineer shall complete Appendix J10 for each well for step-drawdown pumping test activities.

(ii) Constant discharge Test

The **hydrogeologist / water resources engineer** shall conduct a constant rate pumping test for a minimum period of six (6) hours at a designed abstraction rate. The constant rate pumping test shall not be concluded until the water level has stabilized. The hydrogeologist / water resources engineer shall complete Appendix K.11 for each well for recording Constant discharge test activities.

(iii) Recovery Test

The **hydrogeologist** / **water resources engineer** shall conduct the Recovery test immediately after the ceasation of step draw down / constant discharge test to acquire water level recovery data. Efforts shall be made to ensure that such data is obtained until the recovered water level in the Well is the same as the initial static water level. The interval for measurement of recovered level shall be the same as indicated in Table 5.

The hydrogeologist / water resources engineer shall complete Appendix A12 for each well for recording Recovery Test pumping test activities.

5.11.4 The pumping test recommendation form Appendix N shall be completed for each well and shall be duly signed.

5.12 Well Head Completion

The following shall be ensured:

(a) The top of the casing shall be cut off smooth and level, be free from dents and cracks, and shall terminate at least one 300mm above the ground surface. All wells shall be securely capped.
(b) Underground installations leading from the well shall employ a pitless adapter which does not require welding at the casing.
(c) Pitless units or adapters shall be constructed and installed so as to prevent the entrance of contaminants into the well.
(d) Surface drainage shall be diverted away from the well head so that water is not allowed to stand around the casing.

5.12.1 Every well shall be completed with the following:

(i) Access Port

Every water supply well shall be equipped with a usable access port or air line securely covered by a threaded plug. The access port shall be at least 12mm inside diameter opening so that the position of the water level can be determined at any time. Such port shall be installed and maintained in such manner as to prevent entrance of water or foreign material.

(ii) Well Driller Identification Plate

Every water well shall have a Well Driller Identification Plate constructed of a durable weatherproof, rustproof material and shall be firmly secured to either the above ground portion of the well casing, surface grout pad or enclosure floor around the casing where it is readily visible. The identification plate shall contain the following:

(a) driller's name, registration number, well drilling permit number.
(b) stamped or imprinted permanent legible markings showing the:

- total depth of well (m);
- yield, in litres per second (l/s) and date measured;
- static water level in metres, date measured; and
- date well completed.
- date the pump was installed;
- the depth of the pump intake; and
- the kilowatt rating of the pump.

(iii) Valved Flow

Every artesian well that flows under natural artesian pressure shall be equipped with a valve so that the flow can be regulated. Well owners shall be responsible for the installation, operation and maintenance of the valve.

(iv) **Pitless Adapters** or pitless units shall be allowed as a method of well head completion under the following conditions:

(a) The pitless device shall be manufactured specifically for the purpose of water well construction;
(b) The pitless device shall be compatible with the well casing;
(c) The top of the pitless device shall extend at least one metre (1m) above ground surface;
(d) The pitless device shall have an access port.

(v) All openings for piping, wiring, and vents shall enter into the well at least 1m above ground surface, except where pitless adapters or pitless units are used, and shall be adequately sealed to preclude the entrance of contaminants into the well.

5.13 Site Restoration and Clean Up

Upon completion of all works, in connection with drilling, development, and pumping test, the well shall be capped. The site shall be returned to its original or better condition.

5.14 Disinfection and Decontamination

(a) After construction, the water well driller shall collect sample for determination of bacteriological quality and thereafter disinfect the well. The water well driller shall use a chlorine solution prepared with calcium hypochlorite in powdered or tablet form for Water Well disinfection. Sufficient chlorine compound shall be placed in the Water Well to achieve 100 part per million of residual chlorine in the water standing in the Water Well. About 0.1065litres (three ounces) of hypochlorite containing 65 percent to 75 percent available chlorine is needed per 378.5litres (100

gallons) of water for at least a 100ppm chlorine residual. As an example, a well having a diameter of 150mm or six inches, has a volume of about 17.68litres per metre or (1.5 gallons per foot). If the well has 200 feet or 60.96m of water, the minimum amount of hypochlorite required would be 9 ounces as shown below:

i.e. 17.68 litres/m x 60.96m = 1077.773 litres at 0.1065 litres of hypochlorite per 378.5 litres of water; = (1077.73/378.5) x 0.1065 or 0.303245 litres of hypochlorite.

OR

(1.5 gallons/foot x 200 feet = 300 gallons at 3 ounces per 100 gallons; 3 ounces x 3 = 9 ounces)

Table 6 presents a guideline on chlorine dosage preparation.

(b) The chlorine compound shall be placed by one of the following methods;

(i) A double capped perforated pipe filled with granular chlorine compound may be lowered to the bottom of the Water Well then gradually raised and agitated to dissolve the chlorine compound throughout the length of the Water Well below the water level.
(ii) For Water Well less than 30m deep, chlorine tablets shall be poured down the Water Well from surface.
(iii) A concentrated chlorine solution shall be placed in the Water Well through a hose or tremie pipe of sufficient length to extend to the bottom of the Water Well. The disinfecting agent shall be applied through the hose which shall be raised and lowered to achieve uniform distribution of the solution throughout the Water Well.
(iv) All accessible portion of the Water Well above the water level shall be wetted with a chlorine solution.

5.15 Water Quality

Water sample shall be collected from each water well and analyzed for all the elements in Appendix I in accordance with the requirements of the Nigeria Standard for Drinking Water Quality NIS 554: 2007. The water quality analysis report shall be certified by registered appropriate water analyst.

Table 6 - Guidelines for Chlorine Dosage Preparation

Chlorine Compound Required to Dose 30m (100ft) of Water-Filled Well at 50 mg/L									
Casing Diameter (in.)	Casing Diameter (mm)	Volume of water in casing per 30m (100ft) of water depth (gallons)	Volume of water in casing per 30m (100ft.) of water depth (litres)	Amount of Chemical Compound needed for each 30m (100ft) of water					
				Calcium Hypochlorite[1] (65% available Cl_2)	Calcium Hypochlorite[1] (65% available Cl_2) (grams)	Sodium Hypochlorite[2] (12 trade %)	Sodium Hypochlorite[2] (12 trade %) Litres	Liquid Chlorine[3] (100% available Cl_2) (pounds)	Liquid Chlorine[3] (100% available Cl_2) (grams)
4	100	65.28	247.08	0.7oz	19.84	3.5oz	0.12	0.03	13.61
6	150	146.20	553.37	1.5oz	42.52	7.8oz	0.28	0.06	27.22
8	200	261.10	988.26	2.7oz	76.54	13.9oz	0.49	0.11	49.90
10	250	408.00	1544.28	4.2oz	119.07	1.4pt	0.66	0.17	77.11
12	300	587.50	2223.69	6.0oz	170.10	2.0pt	0.95	0.25	113.40
16	400	1044.00	3951.54	10.7oz	303.34	3.5pt	1.66	0.44	199.58
20	500	1632.00	6177.12	1lb 1oz	481.94	0.7gal	2.65	0.68	308.45
24	600	2350.00	8894.75	1lb 8oz	680.39	1.0gal	3.79	0.98	444.53
30	750	3672.00	13898.52	2lbs 6oz	1077.28	1.5gal	5.68	1.53	694.01
36	900	5287.00	20011.30	3lbs 6oz	1530.87	2.2gal	8.33	2.21	1002.46
48	1200	9400.00	35579.00	6lbs 1oz	2749.90	3.9gal	14.76	3.92	1778.11
60	1500	14690.00	55601.65	9lbs 7oz	4110.68	6.1gal	23.09	6.13	2780.57

Note 1: *The quantity of Calcium Hypochlorite is based on 65 percent available chlorine by dry weight.*
Note 2: *The quantity of Sodium Hypochlorite is based on 12-trade-percent available chlorine by US liquid measure (Trade percent is a term used by chlorine manufacturers. Trade percent x 10 = grams of available chlorine in 1L of solution.)*
Note3: *Quantity of liquid chlorine is based on 100 percent available chlorine by weight.*
Source: "Well Construction Standards Rules" **(**IDAPA 37.03.09).

5.16 Pump Selection

5.16.1 Motorized Pumps

A variety of pumps suited to specific conditions is used for motorized pumping. The three broad categories according to the source of energy are:

(a) The solar pump
(b) Diesel driven positive displacement pumps
(c) Electric submersible pumps.

Table 7 should be used as a broad guideline on the type of pump to be used. In certain cases different types of pump may be more suitable and these should be investigated.

Table 7 - Guidelines on Pump Types

Pump Type	Guidelines on Suitability
Electrical Submersible Pumps (Centrifugal type)	• Most economical and convenient pumps in cases where electrical supply is available - normally the first choice for Water Well pumps. • Lower maintenance and running cost. • More efficient at higher volumetric capacity and lower heads. • Less prone to vandalism as most of the assembly is housed inside the Water Well. • Can function satisfactorily even in Water Wells that are not straight and vertical. • Less suitable when the head fluctuations are high as it has direct impact on discharge. • Not suitable for electrical supply with more than 10% voltage fluctuations
Diesel-Driven Positive Displacement Pumps	• Economical for rural and remote areas where electrical supply is not available • More suited for higher discharge and head (head x volume factor more than 1300m^4 - for factors less than that normally solar pumps are more suitable) • Not very suitable for long hours of pumping • More efficient at higher heads • Higher running and maintenance cost • Not very suitable for Water Wells that are not straight and vertical
Solar Pumps	• More economical under lower pumping head (normally less than 50m) and volumetric abstraction (20 to 25 m^3/day) • Prone to vandalism and therefore may not be feasible in remote areas with no attention • Technology still developing
Electric-Driven Non-submersible type Pumps	• Also commonly referred to as Turbine Pumps and are used for higher discharges • Not preferred over the submersible types (provided their motor size is suitable for installation) for a similar set of conditions
Electric-Driven Positive Displacement Pumps	• These may be used, where electrical power is available, in the same supply applications as for the diesel-driven variety and offer the advantage of lower capital and running costs. However, it is critical to ensure that the motor chosen can supply the torque required to start the pump, bearing in mind that the starting torque usually exceeds the running torque for this type of pump

Irrespective of the type of pump, the following general principles shall be followed with regard to pump selection:

(a) Maximum diameter of pump and motor for submersible pumps shall not exceed 90% of the finished diameter of the well at the depth where the pump is to be installed.
(b) While selecting the size of the pump, the total head (or a head range) against which the pump may be operating, should always be calculated as per example shown below:

Total Dynamic Head (HT) = Expected Pumping Water Level in the well (HPWL) **-** *normally a range to take care of fluctuation in water level* **+** *Static Head from the top of the well to the point of discharge (HS)* **+** *Frictional Head Losses along the line (HF)*

(c) The optimum pump size shall be selected using the pump performance curves and the calculated total head such that the pump operates within its optimum efficiency range.
(d) The pump manufacturer's instructions on installation and operating conditions shall always be followed.
(e) The pump shall be capable of operating under the specific water quality conditions, such as temperature, suspended solids load, pH, conductivity and other constituents, without unacceptable degradation.
(f) Pumps, motors and cables shall always comply with established Nigerian Industrial Standards and ISO standards.

5.16.2 Installation of Pumping Equipment

Submersible pumps shall be installed in water wells in strict compliance to the pumping test recommendations as well as compliance with the following:

(a) The minimum sustainable yield of the well shall be at least 0.5litre per second on 6hours basis unless otherwise specified by Hydrogeologist/Water Resources Engineer.
(b) General guidelines and instructions of the manufacturer on the installation of pumping equipment shall always be followed. All material and equipment shall conform to requirements specified by Nigerian Industrial Standards
(c) To protect the pump from running dry (that can damage the pump and the motor) a run-dry protection mechanism shall be provided that trips off the pump before the water level reaches the pump intake. It shall also have an upper level control to re-start the pump once the water level recovers to an appropriate level.
(d) A tap shall be installed at the discharge line to collect water sample and should be secured from unauthorized access.

(e) All the electric cables must comply with requirements specified in the relevant Nigerian Industrial Standards for such electric cables.
(f) During the installation of pumps and operations any direct introduction of lubricants and fuel shall be avoided in the well.
(g) The equipment and assembly at the well head should be protected by a concrete structure of suitable design and size, according to the guidelines in the Table 8 and figures 4 and 5.

Table 8 - Guidelines on Water Well Protection Structure

Pump type	Structure Details
Electrical Submersible Pump	A concrete structure (in cases where the Water Well is in the open and in an unprotected area) divided into two chambers; one to house the electrical panel and the other to house the base plate, water meter, valve etc. The two chambers should have separate access lockable doors/manholes.
Electrical turbine pumps or positive displacement pump	Similar to the above but the second chamber to house the mechanical assembly should be of a suitable size.
Diesel Driven Pumps	A concrete or masonry structure with cemented flour (to avoid the risk of oil seepage through the ground to contaminate the aquifer) and proper ventilation. The size of the housing should be sufficient to provide storage facilities for the diesel fuel oil. The ceiling could be of corrugated iron or equivalent but firmly secured to the structure.
Solar pumps	Solar pumps require open space and, as such, can be housed in any structure. The area around the solar panel and the Water Well should be fenced and protected to secure against vandalism. The fence should be at least 5 m away from any edge of the solar panel.

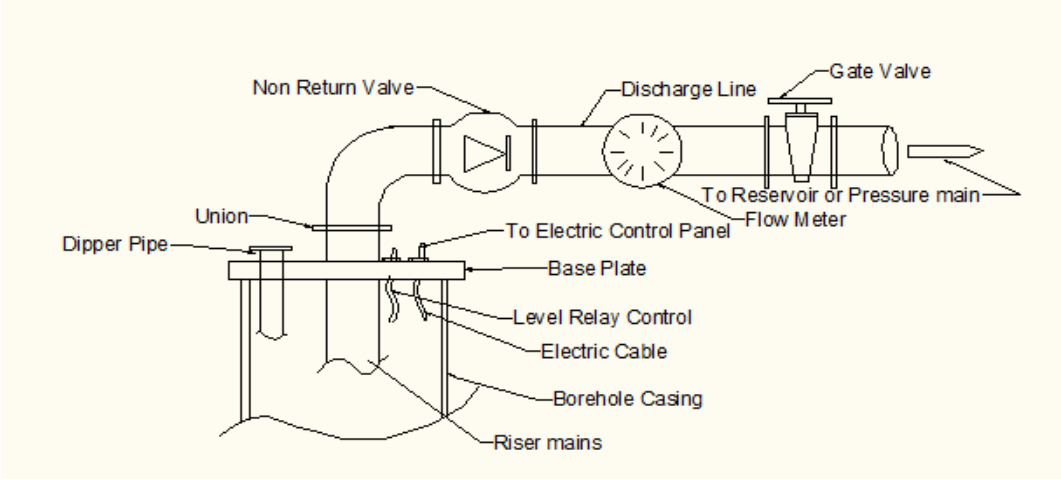

Figure 4 - General Layout of Pumping Equipment Installation at the Wellhead – Electrical Pumps

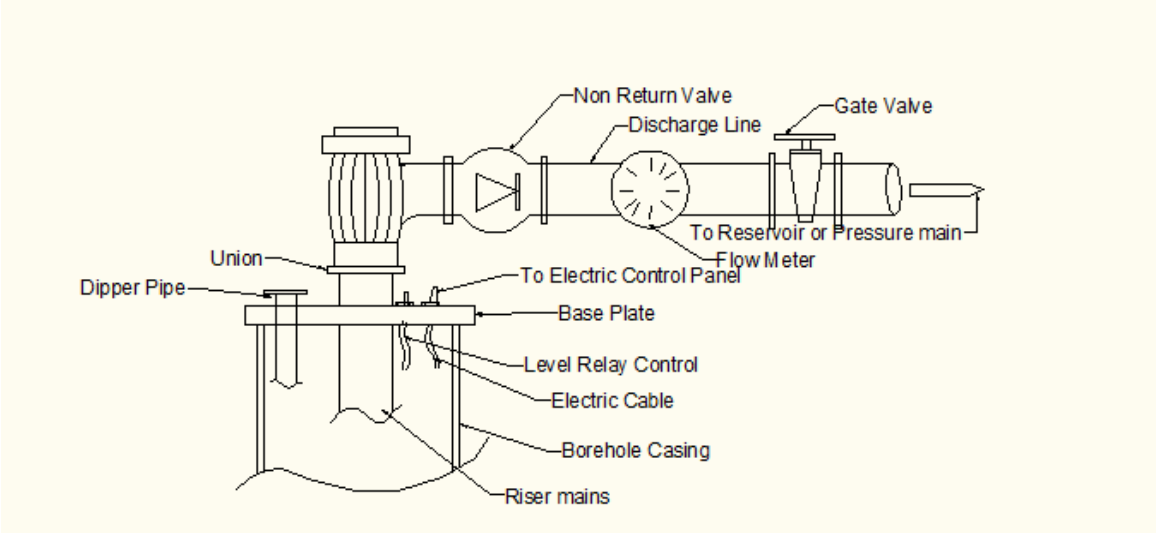

Figure 5 - General Layout of Pumping Equipment Installation at the Wellhead –Non-submersible Pump

5.16.3 Hand pumps

Regardless of the choice of the handpump, the following general principles shall be followed in the selection and installation of handpump in any water well:

(a) The minimum sustainable yield of the well shall be at least 0.25 litres/s on a 6hours pumping basis unless otherwise specified by Hydrogeologist or Water Resources Engineer.
(b) Manufacturer's instructions on the installation and use shall be followed.

(c) All materials used for construction and installation shall comply with requirements specified in Nigerianl Industrial Standards for such materials
(d) Water quality shall be taken into consideration in selecting appropriate material (i.e. uPVC, Galvanized Iron, Mild Steel or Stainless Steel) for the rising main, connecting rods and cylinder.
(e) Maximum outer diameter of the cylinder should not be more than 90% of the finished diameter of the Water Well at the depth where the cylinder is to be installed.
(f) All the couplings and joints should be such that the rising mains are capable of supporting its entire weight including the water column.

5.16.4 Rising Mains

The following general principle shall be used in selecting the size, type and material of rising mains:

(a) The rising main shall be of steel for positive displacement pumps and non-submersible centrifugal pumps (associated with rotating drive shaft), whilst for submersible pumps it could be of steel, GI, uPVC or flexible hose type. The material and type must comply with requirements specified by Nigerian Industrial Standards for the materials from time to time.
(b) All the couplings, joints and supports shall be such that the rising mains is capable of supporting its entire weight, and that of the pump, including the weight of the water column.
(c) The rising mains and drive shaft (wherever applicable) shall follow pump manufacturer's specifications.
(d) The rising mains shall be capable of withstanding water pressure at least 25% in excess of that expected during the pumping operations, allowing for the pressure due to the discharge altitude and friction head losses in the case of a remote discharge point.

5.17 Abandonment of Water Well

The Well Driller shall use one (1) of the following methods as applicable for proper abandonment of any well:

(a) Any well which has to be temporarily out of service shall be sealed with a water-tight cap or seal compatible with casing and installed so that it cannot be removed easily by hand.
(b) Any well which has to be permanently abandoned shall be abandoned in accordance with the following procedures:

    (i) All casing and screen materials shall be removed prior to initiation of abandonment procedures if such removal will not cause or contribute to contamination of the groundwater. Any casing not grouted in accordance with provisions of this code shall be removed

or properly grouted. The entire depth of the well shall be checked before it is sealed to ensure freedom from obstructions that may interfere with sealing operations. Approved grout shall be pressure pumped to fill any voids outside of the casing. A sufficient volume shall be used to completely fill the well and annular space.

(ii) In the case of gravel-packed wells in which the casing and screens have not been removed, neat-cement, or bentonite grout shall be injected into the well completely filling it from the bottom of the casing to the top.

(iii) Wells constructed in unconsolidated formations shall be completely filled with cement grout, or bentonite grout by introducing it through a pipe extending to the bottom of the well which can be raised as the well is filled.

(iv) Wells constructed in consolidated rock formations or that penetrate zones of consolidated rock may be filled with cement grout, bentonite grout, sand, gravel or drill cuttings opposite the zones of consolidated rock. The top of the cement grout, bentonite grout, sand, gravel or cutting fill shall terminate at least 3metres below the top of the consolidated rock or 1.5metres below the bottom of casing. Cement grout or bentonite grout shall be placed beginning 3metres below the top of the consolidated rock or 1.5metres below the bottom of casing and extend 1.5 meters above the top of consolidated rock. The remainder of the well, above the upper zone of consolidated rock, shall be filled with cement grout or bentonite grout up to land surface. For any well in which the depth of casing or the depth of the bedrock is not known or cannot be confirmed, then the entire length of the well shall be filled with cement grout or bentonite grout up to land surface.

(c) The owner shall be responsible for permanent abandonment of a well except that:

(i) The well driller is responsible for well abandonment if abandonment is required because the driller improperly locates, constructs, repairs or completes the well; or

(ii) The person who installs repairs or removes the well pump is responsible for well abandonment if that abandonment is required because of improper well pump installation, repair or removal.

5.18 Water Well Completion Report

5.18.1 A water well completion report shall be prepared for each well drilled and each page shall be dully signed and stamped by the Certified Hydrogeologist in charge. The well completion report shall have all the forms in the appendix of this Code duly completed as Appendixes and shall be deemed incomplete if any of the forms is missing.

5.18.2 A copy each of the water well completion report shall be submitted by the Hydrogeologist/Water Resource Engineer to the client and agencies issuing permit/license.

6. Source Protection

6.1 General Protection of Groundwater Quality and Resources

Water used for cooling parts of engines, air compressors or other equipment shall not be returned to any part of the groundwater system. A well shall not be used for disposal or injection of any substance, including surface water, groundwater or any liquid, gas or chemical associated with the drilling.

6.2 Maintenance and Repair of Wells

(a) Every well shall be maintained by the owner in such a condition that will conserve and protect the groundwater resources and will not be a source or channel of contamination or pollution to the water supply of that well or any aquifer.
(b) All materials used in maintenance of any well shall meet the requirements of this code.
(c) Broken, punctured or otherwise defective or unserviceable casing, screens, fixtures, seals or any part of the wellhead shall be repaired or replaced. The well shall be plugged in accordance with the requirements of this code if that repair or replacement is not performed.
(d) Repairs to wells originally completed with the wellhead terminating below ground (buried seal) should include extending the well casing 1m above the finished surface. The casing extension material shall be of similar material to the original casing (for example, steel to steel and plastic to plastic). On steel casing the joint must be welded, coupled or threaded. On plastic casing, the joint must be glued or fused. All joints and extensions must be sealed to prevent contamination from entering the groundwater. Sealing material must not be a contaminant.

6.3 Cross connections between wells and other systems or equipment containing water or other substances of unknown or questionable safety, including pesticides and fertilizers, are prohibited.

6.4 Sources of Contamination

All Wells shall be protected from all sources of contamination in line with the requirements of subclauses 5.1 (d), 6.3, 5.16.2 (e), 5.12 (d), 5.10 (a) and 5.36 of this code.
Fuel dump pits shall be encased in a water tight reinforced concrete structure to prevent contamination of water wells due to leakages from underground storage tanks.

6.5 Wellhead Protection for Public Water Supply Well

Wellhead Protection Area shall be in accordance with the minimum sitting and separation distances specified in subclause 5.1.

Appendix A

Federal Ministry of Water Resources
Application for Well Construction Permit

A.1 Background Information

Date of Application: ……

Name of Owner: ……

Address: ……..

……

Telephone Number(s): ……..

Location of Water Well: ……

Latitude: …… Longitude: ……

Address (if different from owners address): ……...

……

A.2 Well Information

Type of Water Well (Indicate One)

[ ] Public Water Supply

[ ] Individual Domestic Water Well

[ ] Industrial Water Well

[ ] Agricultural Water Well

[ ] Monitoring Water Well

[ ] Others (specify): _____

_____

A.3 Well Plan and Construction Details

(i) Attach dully endorsed hydrogeological / geophysical report.

(ii) The Water Well pump will be of the _____ (submersible or handpump)

A.4 Declaration

I……
(Name and Title) state that I have knowledge of the facts herein set and that the same are true and correct to the best of my knowledge and belief and are made on good faith.

Signature: …….. Date: ……..

A.5 Authorized Agency Clearance

[ ] Approved
[ ] Disapproved
[ ] Hold for further evaluation

Remark(s): ……

……

Name: ……
(Authorized Representative)

Rank: ……

Signature: …… Date: ……..

(FOR AGENCY USE ONLY)

Inspection of the Water Well site was conducted on ……

by ……..

Findings: ……....

……

Review by the Water Resource Engineer / Hydrogeologist.

Date : ……

Recommandation

[ ] Approved [ ] Not Approved

Reasons for Disapproval: ……....

……...

Signature: …… Date: ……

Administrator Well Construction Permit No: _____

Date Issued: …… Expiration Date: ……

Completed application form should be submitted with evidence of payment of a prescribed fee per Water Well.

Appendix B

Federal Ministry of Water Resources
Application For Well Driller's License

B.1 Section A - General

(i) Date of Application: ……

(ii) Type of Application

[ ] New

[ ] Renewal (if renewal, indicate previous Well Driller's License No.: ……

B.2 Section B - (For Individual Application Only)

(i) Name of Applicant: ……

……

(ii) Residential / Postal Address: ……

……

……

(iii) State: …… LGA: …… Ward: ……..

(iv) Telephone No.: ……

(v) The following documents, statements and certifications shall be attached to this application and submitted herewith:

(a) Evidence of applicant's 3 years post qualification experience in drilling
(b) Curriculum vitae (CV) of applicant
(c) Qualifications and experience statements
(d) Recommendation from a license driller or registered practicing professional (Hydrogeologist or Engineer)
(e) Evidence of Tax Clearance Certificate

(vi) I, …….. acknowledge that the foregoing information provided by the above applicant are to the best of my knowledge correct and that he / she has the required experience and skills to operate as a professional driller.

Registration No.: …….. Seal: ….....

Date: ……

B.3 Section C - (For Corporate Application Only)

(i) Name of Corporate Entity: ……....

(ii) Location/Postal Address: ……....

……

……

……

(iii) State: ……... LGA: …… Ward: ……...

(iv) Authorized representative for the Corporate Entity

Name: ……..

Designation: …… Telephone No.:……

(v) The following documents shall be attached to this application and herewith:

(a) Certificate of Incorporation
(b) Company Profile
(c) Evidence of Tax Clearance Certificate
(d) Evidence of payment of VAT

(vi) Signature of Authorized representative/Date: ……

B.4 Section D - (For Official Use)

(i) Recommendations

[ ] Approved

[ ] Not Approved

(ii) Reasons for Non – approval: ……...

……

……

(iii) Administrator's Signature: …… Date: ……

(iv) Well Driller's License No.: ……

(v) Date Issued: ……

(vi) Expiration Date: ……..

*Completed application form **must** be submitted with evidence of payment of prescribed license fee*

Appendix C

Water Well Siting Details

(Information to be supplied by the hydrogeologist/Geophysicist)

Water Well Reference No**:**		Owner:
Location :	Community:	Address:
Coordinates Lat:	Long	UTM :
Well Permit No.	Date Issued	Issuing Authority
State:		*LGA:*

Attach Sketch Location Map with all controls and reference bench marks

Geophysicist:

Consideration: …… **Check**: ……. **Remark**: ……..

Community informed Desirable / Not Desirable

Rig accessibility Yes/No

Community accessibility Yes/No

Perceived environmental problem (*indicate*): ……..

……

Average distance of nearest pollution source (m):

Geophysical Survey Yes/No

Geophysical methods used: ……..

(Specify methods)

Recommended drilling depth: **Expected yield (range):** ……....

Reason for the selection of site: ……..

……

Name*:* ……..

(Hydrogeologist /Geophysicist)

Signature/Stamp/Date

Attach with this sheet: Geophysical plots, further elaboration on any of the above point (if required)

Appendix D

Water Well Drilling Details

(Information to be supplied by the hydrogeologist/Water Resources Engineer)

Water Well Reference No:		Owner:
Location :	*Community*:	Address:
Coordinates *Lat:*	*Long*:	*UTM :*
Well Permit No.	Date Issued:	Issuing Authority
State:		*LGA:*
Name of Drilling Company:		*Driller's License No:*

Attach Sketch Location Map with all controls and reference bench marks

Drilling Schedule: …….....

Date of Commencement: **Date of Completion**: **Geologic Formation**:

Total Depth Drilled: **Drilled Diameter**: **Drilling Method**:

Penetration rate: **Blow-out Yield/Expected Yield**: **Water Level**:

Aquifers Intercepted Thickness Range:

From: …… To: …… From: ……..To: ……. From: ……. To: ……....

Casing Schedule*:* Material: …… Diameter: …… Depth Ranges: ……...

Screen Schedule: Material: …… Diameter: ……. Depth Ranges: ……..

Type: ……. Slot Size: …….. Open Area %: ……...

Gravel Packing Schedule

Type (Natural / Artificial): ……..Type of Material: ……Grain Size: ……

Used Volume: ……

Grouting Schedule: Depth of grout: …….. Depth Ranges: ……..

Development Schedule: Method of Development: ……. Duration: ……

Water Quality: Temperature: ……. TDS/EC: …….. pH: ……

Pumping Test Schedule: Date of Test: …… Static Water Level: ……

First Step Pumping: Pump Capacity (Hp/kW): ……..… Type: …… Discharge: ……...

Duration before stabilization: …… Dynamic Water Level: ……. Drawdown: ……..

Second Step Pumping: Water Level: …….. Discharge: ……...

Duration before stabilization: …… Dynamic Water Level: …….. Drawdown: ……....

Third Step Pumping: Water Level: …….. Discharge: ……

Duration before Stabilization: …… Dynamic Water Level: ……. Drawdown: ……..

Recovery Schedule (Include curves): Duration: …… Dynamic Water Level: …….

% Recovery: ……

Productivity Status of Borehole: Productive/ Not Productive

Decommissioned: Yes/No

Pump Installed: Make and Model: …….. Q & H: ……..

Capacity (Hp/kW): …….. Depth: ……

Riser Pipe: Material: …… Diameter: ……. Drawdown: …… Date: ……

Name: _____

(Hydrogeologist/Water Resources Engineer)

Signature/Professional Stamp/Date: ……....

Appendix E

Water Well Construction Details

(Information to be supplied by the Driller / Hydrogeologist / Water Resources Engineer)

Water Well Reference No**:**

Owner:

Location :

Community:

Address:

Coordinates *Lat:*

Long:

UTM :

Well Permit No.

Date Issued:

Issuing Authority

State:

LGA:

Name of Driller:

Driller's License No:

Drilling				**Casing**			
From (m)	To (m)	Diameter (mm)		From (m)	To (m)	Material/ Thickness (mm)	Diameter (mm)

Screen							
From (m)	To (m)	Diameter (mm)	Type (m)	Material	Thickness (mm)	Slot Size	Open Area

Gravel/Cement Grout							
From	To	Material	Size	Thickness	Remark		

Water WellCap Yes/No	**Cement Slab** Thickness	Size
Alignment/Verticality Test Remark		
General Remarks		

Name: _____

Hydrogeologist/Water Resources Engineer

Signature / Professional Stamp/Date: ……....

Appendix F
Lithological Logging

(Information to be supplied by the hydrogeologist/Water Resources Engineer)

Water Well Reference No: Owner:

Location : *Community*: Address:

Coordinates *Lat:* *Long*: *UTM :*

Well Permit No. Date Issued: Issuing Authority

State: *LGA:*

Name of Driller: *Driller's License No:*

Well Logged by:

Depth (m)	Description	Colour*	Grain size*	Texture*	Degree of weathering*	Stratigraphic unit (if known)*	Remarks (e.g. mineralogy, drilling, water etc)	Penetration rate (min/m)	Discharge	EC/ TDS

*Data to be recorded at a minimum of 1metre intervals- add more sheets if required * See attached sheet for codes*

Name (Hydrogeologist/Water Resources Engineer): ……

Signature/Professional Stamp/Date: ……..

Appendix G

Abbreviations for Lithological Logging

Colour *(use combinations if needed)*			
Gr - grey	Gn - green	Br-brown	Or – orange
Bg-beige	Rd-red	Pk- pink	Wt – white
Shade			
L-light	M-medium	D-dark	
Grain size			
VF - very fine	F - fine	M - medium	C – coarse
VC - very coarse			
Texture *(use more than one as applicable)*			
D - Dense, hard	F - fractured	U- unconsolidated	PC- partly consolidated
L - laminated	H- homogeneous	C - clast supported	M- matrix supported
Degree of weathering			
F-fresh	L-light	M-moderate	D-deeply
Formation / Stratigraphic unit (if known)*			

** Add Codes based on the local stratigraphic nomenclature*

Appendix H

Groundwater Sampling Form

(Information to be supplied by the hydrogeologist/Driller)

Water Well Reference No:		Owner:
Location :	*Community*:	Address:
Coordinates *Lat:*	*Long*:	*UTM :*
Well Permit No.	Date Issued:	Issuing Authority
State:		*LGA:*
Name of Driller:		*Driller's License No:*

Sketch Location Map with all controls and reference bench marks

Date of Sampling	Date of Submission
Depth of Sample (if Applicable)	Other Source
Sampling Method Used	
No. of Samples Collected	Acidic Sample (Y/N)
Constituents Request Form Attached (Y/N)	

Field Measurements

Temperature TDS mg/l pH

Name (Hydrogeologist/Water Resources Engineer): **…….....**

Signature/Professional Stamp/Date: ……..

Appendix I.1

Water Quality Analysis Report (Regular Parameters)
Based on Nigerian Standard for Drinking Water Quality (NSDWQ)

Water Well Reference No: Owner:

Location : Community: Address:

Coordinates Lat*:* *Long*: UTM *:*

Well Permit No. Date Issued: Issuing Authority

State*:* LGA*:*

Name of Water Analyst: Laboratory*:*

Sample No*:* Date Collected Date Analyzed

S/No	Parameter	Unit	Maximum NSDWQ Permitted Level	Analyzed Sampled Level	Remark
1.	**Physical**				
	Colour	TCU	15		
	Odour	-	Unobjectionable		
	Taste	-			
	Temperature	^{o}C	Ambient		
	Turbidity	NTU	5		
2.	**Chemical**				
	pH		6.8-8.5		
	Chloride(Cl)	mg/L	0.01		
	Fluoride (F^-)	mg/L	1.5		
	Hardness ($CaCO_3$)	mg/L	150		
	Iron (Fe^{2+})	mg/L	0.3		
	Magnesium (Mg^{2+})	mg/L	0.20		
	Manganese (Mn^{2+})	mg/L	0.2		
	Nitrate (NO_3^{2-})	mg/L	50		
	Nitrate (NO_2^-)	mg/L	0.2		
	Sodium (Na^+)	mg/L	200		
	Sulphate (SO_4^{2-})	mg/L	100		
	Total Dissolved Solids (TDS)	mg/L	5		
3.	**Microbiological**				
	Thermo-tolerant Coliform (*E.coli*)	cfu/100mL	Nil		
	Feacal *Coliform*	cfu/100mL	Nil		
	Streptococcus	cfu/100mL	0		
	Total Coliform Count	cfu/100mL	10		

Name (Water Analyst with IPAN Registration Number): …….....

Signature/Professional Stamp/Date: …….....

Appendix I.2

Water Quality Analysis Report (General Parameters)
Based on Nigerian Standard for Drinking Water Quality (NSDWQ)

Water Well Reference No: Owner:

Location : Community: Address:

Coordinates Lat: Long: UTM :

Well Permit No. Date Issued: Issuing Authority

State: LGA:

Name of Water Analyst: Laboratory:

Sample No: Date Collected Date Analyzed

S/No	Parameter	Unit	Maximum NSDWQ Permitted Level	Analyzed Sampled Level	Remark
1.	**Physical/Organoleptic**				
	Colour	TCU	15		
	Odour	-	Unobjectionable		
	Taste	-	"		
	Temperature	^{o}C	Ambient		
	Turbidity	NTU	5		
2.	**Chemical (A) - Inorganic**				
	Aluminum(Al)	mg/L	0.2		
	Arsenic(As)	mg/L	0.01		
	Barium(Ba)	mg/L	0.7		
	Cadmium(Cd)	mg/L	0.003		
	Chloride(Cl)	mg/L	240		
	Chromium(Cr^{6}+)	mg/L	0.05		
	Conductivity	US/L	1000		
	Copper (Cu)	mg/L	1		
	Cyanide (CN^{-})	mg/L	0.01		
	Fluoride(F^{-})	mg/L	1.5		
	Hardness(as $CaCO_3$)	mg/L	150		
	Hydrogen Sulphide (H_2S)	mg/L	0.05		
	Iron (Fe^{+2})	mg/L	0.03		
	Lead (Pb)	mg/L	0.01		
	Magnesium (Mg^{+2})	mg/L	0.2		
	Manganese (Mn^{+2})	mg/L	0.2		
	Mecury(Hg)	mg/L	0.001		
	Nickel(Ni)	mg/L	0.02		
	Nitrate(NO_3)	mg/L	50		
	Nitrate(NO_2)	mg/L	0.2		
	pH	-	6.5-8.5		
	Sodium(Na)	mg/L	200		
	Sulphate(SO_4^{2-})	mg/L	100		
	Total Dissolved Solids	mg/L	500		
	Zinc (Zn)	mg/L	3		

Name: (Water Analyst with IPAN Registration Number): ……

Signature/Professional Stamp/Date: ……

Appendix I.3

Water Quality Analysis Report (General Parameters)

Based on Nigerian Standard for Drinking Water Quality (NSDWQ)

Water Well Reference No: Owner:

Location : Community: Address:

Coordinates Lat: Long: UTM :

Well Permit No. Date Issued: Issuing Authority

State: LGA:

Name of Water Analyst: Laboratory:

Sample No: Date Collected Date Analyzed

S/No	Parameter	Unit	Maximum NSDWQ Permitted Level	Analyzed Sampled Level	Remark
	Chemical (B) Organic				
	Detergents	mg/L	0.01		
	Mineral Oil	mg/L	0.003		
	Pesticides	mg/L	0.01		
	Phenols	mg/L	0.001		
	Poly Aromatic Hydrocarbons	mg/L	0.007		
	Total Organic Carbon	mg/L	5		
3.	**Disinfectants/By-Products**				
	Free Residual Chlorine	mg/L	0.2-0.25		
	Trihalomethanes Total	mg/L	0.001		
	2,4,6-Trichlorophenols	mg/L	0.02		
4.	**Radioactive**				
	Radionuclides	mq/L	0.1		
5.	**Microbiological**				
	Total Coliform Count	cfu/mL	10		
	Thermo-tolerant Coliform or E-Coli	cfu/100mL	Nil		
	Feacal Coliform	cfu/100mL	Nil		
	Streptococcus	Cfu/100mL			
	Clostridium Perfringeens Spore	cfu/1mL	0		

Name (Water Analyst with IPAN Registration Number): …….....

Signature / Professional Stamp/Date: …….....

Appendix J

Step Drawdown Test

(Information to be supplied by the Driller / hydrogeologist / Water Resources Engineer)

Water Well Reference No: Owner:

Location : Community: Address:

Coordinates Lat: Long: UTM :

Well Permit No. Date Issued: Issuing Authority

State: LGA:

Name of Driller: Driller's License No:

WL Before the Test Reference Point Pump Intake

Step No Of Time Discharge (m^3/sec) Water Level

Real Time	Hrs.	Mins.	Depth of Water (m)	Drawdown (m)	Container Method (L/s or m^3/hr)	Flow Meter (L/s or m^3/hr)	TDS, Temperature, pH and any other observation
		0					
		0.5					
		1.0					
		2.0					
		3.0					
		4.0					
		5.0					
		6.0					
		7.0					
		8.0					
		9.0					
		10.0					
		12.0					
		14.0					
		16.0					
		18.0					
		20.0					
		25.0					
	0.5	30.0					
		35.0					
		40.0					
		45.0					
		50.0					
	1.0	60.0					
		70.0					
		80.0					
	1.5	90.0					
		100.0					
		110.0					
	2.0	120.0					

Name (Hydrogeologist / Water Resources Engineer**)**: ……

Signature/Professional Stamp/Date: ……

Appendix K

Constant Rate Test

(Information to be supplied by the Driller/Hydrogeologist/Water Resources Engineer)

Water Well Reference No: Owner:

Location : Community: Address:

Coordinates Lat: Long: UTM :

Well Permit No. Date Issued: Issuing Authority

State: LGA:

Name of Driller: Driller's License No:

WL Before the Test Pump Intake

Reference Point Pumping Well/ Observation Well (Tick Appropriate)

Average Discharge (L/sec) Obs Well No. Distance (m) Depth (m)

Time			Water Level		Discharge		Remark
Real Time	Hrs	Min	Depth of Water (m)	Drawdown (m)	Container Method (L/s or m^3/h)	Flow Meter (L/s or m^3/h)	TDS, Temperature, pH and any other observation
		0					
		0.5					
		1.0					
		2.0					
		3.0					
		4.0					
		5.0					
		6.0					
		7.0					
		8.0					
		9.0					
		10.0					
		12.0					
		14.0					
		16.0					
		18.0					
		20.0					
		25.0					
	0.5	30.0					
		35.0					
		40.0					
		45.0					
		50.0					
	1.0	60.0					
		70.0					
		80.0					

Appendix K (Contd.)

Constant Rate Test

(Information to be supplied by the Driller/Hydrogeologist/Water Resources Engineer)

Water Well Reference No: Owner:

Location : Community: Address:

Coordinates Lat: Long: UTM :

Well Permit No. Date Issued: Issuing Authority

State: LGA:

Name of Driller: Driller's License No:

WL Before the Test Pump Intake

Reference Point Pumping Well/ Observation Well (Tick Appropriate)

Average Discharge (L/sec) Obs Well No. Distance (m) Depth (m)

Time			Water Level		Discharge		Remark
Real Time	Hrs	Min	Depth of Water (m)	Drawdown (m)	Container Method (L/s or m^3/h)	Flow Meter (L/s or m^3/h)	TDS, Temperature, pH and any other observation
	1.5	90.0					
		100.0					
		110.0					
	2.00	120.0					
	2.25	135.0					
	2.5	150					
	2.75	165					
	3	180					
	3.5	210					
	4	240					
	4.5	270					
	5	300					
	5.5	330					
	6	360					
	6.5	390					
	7	420					
	7.5	450					
	8	480					
	8.5	510					
	9	540					
	9.5	570					
	10	600					
	10.5	630					
	11	660					
	11.5	690					

Appendix K (Contd.)

Constant Rate Test

(Information to be supplied by the Driller/Hydrogeologist/Water Resources Engineer)

Water Well Reference No: Owner:

Location : Community: Address:

Coordinates Lat: Long: UTM :

Well Permit No. Date Issued: Issuing Authority

State: LGA:

Name of Driller: Driller's License No:

WL Before the Test Pump Intake

Reference Point Pumping Well/ Observation Well (Tick Appropriate)

Average Discharge (L/sec) Obs Well No. Distance (m) Depth (m)

Time			Water Level		Discharge		Remark
Real Time	Hrs	Min	Depth of Water (m)	Drawdown (m)	Container Method (L/s or m^3/h)	Flow Meter (L/s or m^3/h)	TDS, Temperature, pH and any other observation
	11	660					
	11.5	690					
	12	720					
	13	780					
	14	840					
	15	900					
	16	960					
	17	1020					
	18	1080					
	19	1140					
	20	1200					
	21	1260					
	22	1320					
	23	1380					
	24	1440					
	26	1560					
	28	1680					
	30	1800					
	32	1920					
	34	2040					
	36	2160					
	38	2280					
	40	2400					
	42	2520					
	44	2640					

Appendix K (Contd.)

Constant Rate Test

(Information to be supplied by the Driller/Hydrogeologist/Water Resources Engineer)

Water Well Reference No: Owner:

Location : Community: Address:

Coordinates Lat: Long: UTM :

Well Permit No. Date Issued: Issuing Authority

State: LGA:

Name of Driller: Driller's License No:

WL Before the Test Pump Intake

Reference Point Pumping Well/ Observation Well (Tick Appropriate)

Average Discharge (L/sec) Obs Well No. Distance (m) Depth (m)

Time			Water Level		Discharge		Remark
Real Time	Hrs	Min	Depth of Water (m)	Drawdown (m)	Container Method (L/s or m^3/h)	Flow Meter (L/s or m^3/h)	TDS, Temperature, pH and any other observation
	46	2760					
	48	2880					
	50	3000					
	52	3120					
	54	3240					
	56	3360					
	58	3480					
	60	3600					
	62	3720					
	64	3840					
	66	3960					
	68	4080					
	70	4200					
	72	4320					

Name (Hydrogeologist/Water Resources Engineer): ……..

Signature/ Stamp/Date: ……..

Appendix M
Recovery Test

(Information to be supplied by the Driller / Hydrogeologist / Water Resources Engineer)

Water Well Reference No: Owner:
Location : *Community*: Address:
Coordinates *Lat:* *Long*: *UTM :*
Well Permit No. Date Issued: Issuing Authority
State: *LGA:*
Name of Driller: *Driller's License No:*
WL Before the Test Pump Intake
Reference Point

Time			Water Level		Time			Water Level	
Real Time	Hours	Minutes	Depth of Water (m)	Residual Drawdown (m)	Real Time	Hours	Minutes	Depth of Water (m)	Residual Drawdown (m)
		0				8.5	510		
		0.5				9	540		
		1				9.5	570		
		2				10	600		
		3				10.5	630		
		4				11	660		
		5				11.5	690		
		6				12	720		
		7				13	780		
		8				14	840		
		9				15	900		
		10				16	960		
		12				17	1020		
		14				18	1080		
		16				19	1140		
		18				20	1200		
		20				21	1260		
		25				22	1320		
	0.5	30				23	1380		
		35				24	1440		
		40				26	1560		
		45				28	1680		
		50				30	1800		
	1	60				32	1920		
		70				34	2040		
		80				36	2160		
	1.5	90				38	2280		
		100				40	2400		
		110				42	2520		
	2	120				44	2640		
	2.25	135				46	2760		
	2.5	150				48	2880		
	2.75	165				50	3000		
	3	180				52	3120		
	3.5	210				54	3240		
	4	240				56	3360		

Appendix M (Contd.)
Recovery Test

(Information to be supplied by the Driller / Hydrogeologist / Water Resources Engineer)

Water Well Reference No: Owner:

Location : *Community*: Address:

Coordinates *Lat:* *Long*: *UTM :*

Well Permit No. Date Issued: Issuing Authority

State: *LGA:*

Name of Driller: *Driller's License No:*

WL Before the Test Pump Intake Reference Point

Time			Water Level		Time			Water Level	
Real Time	Hours	Minutes	Depth of Water (m)	Residual Drawdown (m)	Real Time	Hours	Minutes	Depth of Water (m)	Residual Drawdown (m)
	4.5	270				58	3480		
	5	300				60	3600		
	5.5	330				62	3720		
	6	360				64	3840		
	6.5	390				66	3960		
	7	420				68	4080		
	7.5	450				70	4200		
	8	480				72	4320		

Name (Hydrogeologist/Water Resources Engineer): ……..…

Signature/Professional Stamp/Date: ……..

Appendix N
Production Pumping Recommendations
(Information to be supplied by the hydrogeologist / water engineer)

Water Well Reference No:		Owner:
Location :	*Community*:	Address:
Coordinates *Lat:*	*Long*:	*UTM :*
Well Permit No.	Date Issued:	Issuing Authority
State:		*LGA:*
Name of Driller:		*Driller's License No:*

Sketch Location Map with all controls and reference bench marks

Date of Drilling	Date of Testing
Total Depth of Water Well	Tested Yield
Reference Point for WL Measurements	Water Level Prior to Testing
Method used for Sustainable Yield Estimate	
Computer Software Used for Sustainable Yield Estimate	
Available Drawdown	t/t' intercept at zero drawdown
Available Specific Capacity	
Adjustments made on predicted/extrapolated drawdown	

Recommendations for Production Pumping

Discharge	Pump Installation Depth
Pumping Hours and Schedule	Expected Pumping Water Level
Water Quality	

Name (Hydrogeologist/Water Resources Engineer): ……...

Signature/Professional Stamp/Date: ……

Appendix P
Water Well Equipping Details
(Information to be supplied by the Water Resources Engineer)

Water Well Reference No:		Owner:
Location :	*Community*:	Address:
Coordinates *Lat:*	*Long*:	*UTM :*
Well Permit No.	Date Issued:	Issuing Authority
State:		*LGA:*
Name of Driller:		*Driller's License No:*

Sketch Location Map with all controls and reference bench marks

Consultant/Hydrogeologist Incharge	Design Engineer
Date of Drilling	Date of Testing
Reference Point for WL Measurements	Water Level Prior to Testing
Total Depth of Water Well	Recommended Yield
Recommended Pumping Hours	Recommended Installation Depth
Expected Pumping Water Level	

Installation Summary

Pump

Type Discharge	Make	Model
Range Motor/Engine	Head Range	Efficiency Range

Motor / Engine

Type	Make	Model
Power	Other	

Rising Main

Type, Size and Length		
Others	Non-return Valve (Y/N)	Gate Valve (Y/N)
Flow Meter (Y/N)		

Name (Hydrogeologist/Water Resources Engineer): ……

Signature/Professional Stamp/Date: ……

Appendix Q

Q.1 Design of Filter Pack for Unconsolidated Formations

To properly design a filter pack and select the appropriate wire wrap screen size, samples of the aquifer formation must be collected. These may be collected during drilling or from archived samples from existing Water Wells. It is desirable to have existing samples for analysis, as this allows the filter pack to be designed and ordered prior to drilling. Although regular sample collection during drilling is acceptable (Section 5.3.3), it is recommended that a split spoon type sampler be utilized to ensure an accurate sample of the formations.

Samples are air dried and disaggregated so that only mineral grains were present. In some cases, some proportion of the coarser fraction constitutes cemented material (such as siltstone or sandstone) or some type of duricrust (such as calcrete, silcrete). In these cases, sieving of the complete sample can create a distorted plot indicating coarser grading than the true sample. As a result, the sample can be examined and these materials removed prior to sieving. However, even large quartz grains or gravels should not be removed.

The samples should then be sieved through a standard set of sieves. Generally the sieves have mesh openings ranging from 0.09mm to 1.40mm. The sieves are arranged with the finest mesh opening on the bottom and the largest on top. The sample is first weighed, then sieved (using a shaking motion or electric vibrator) and the material retained on each sieve weighed.

The data is then plotted both by sample and by Water Well (consisting of a series of samples) on grain size distribution curves as cumulative percentage passed versus grain size (cumulative percentage retained is also sometimes used and is equivalent). A semi-logarithmic scale (the grain size on log scale) can be used to highlight the finer proportions of the samples if they are primarily characterized by fine and fine to medium sands

Q.2 Filter Pack/Screen Selection Methods

The methods used in design of gravel envelope Water Wells generally consists of assessing the nature of the aquifer sands, choosing a filter pack with a suitable grading relative to the aquifer and selecting a screen slot size that will retain at least 90 percent of the filter pack. Assessment of aquifer materials involves determining the finest grain size interval in the zone to be screened and the application of a multiplier to that grain size curve. The specific multiplier chosen is based on the typical sediment size of the complete section. Commonly a four and six times multiplier is used. The four and six multipliers are considered appropriate for uniformly graded materials with a 60 percent passing size less than 0.25mm.

The next step is the choice of the specific filter pack. The available filter pack grain size curves are then plotted for comparison with chosen formation material analyses. An appropriate filter pack grain size distribution falls within the 4 and 6 times plots of the formation material and has a grading similar to the formation material.

Following selection of a filter pack, a screen slot size is then chosen to allow passing of not more than 10% of the filter pack. In the provided examples, the percent of filter pack that will be passed by the screen is found at the intersection of the filter pack grain size curve and a vertical line for the size of the screen slot size.

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