1. DESIGN CONCEPT

1.1 **DESCRIPTION:** THE TERRASPAN® GRS ARCH™ STRUCTURE (HEREIN AFTER REFERRED TO AS "THE STRUCTURE") IS A PROPRIETARY PRODUCT PROTECTED BY BOTH CANADIAN AND US PATENTS OWNED BY TERRATECH CONSULTING LTD. THE "PATENTED" INVENTION ASPECT OF THE STRUCTURE DESCRIBED IN THESE CONCEPTUAL DRAWINGS PERTAINS TO AN INNOVATIVE USE OF GEOTEXTILE REINFORCED SOIL (GRS) TECHNOLOGY TO CONSTRUCT A REINFORCED SOIL ARCH.

- THE INVENTION UTILIZES GRS TECHNOLOGY TO BUILD A GRS COMPOSITE MASS IN THE SHAPE OF AN "ARCH" USING A COMBINATION OF ALTERNATING THINLY SPACED LAYERS OF COMPACTED GRANULAR SOIL MATERIAL AND GEOTEXTILE FABRIC REINFORCEMENT IN A MANNER SO THAT THE REINFORCED SOIL ARCH ITSELF CAN SUPPORT THE DEAD LOAD AND LIVE LOAD. AN IMPORTANT FEATURE OF THE INVENTION IS THAT NO RIGID FOOTING (E.G., CONCRETE OR STEEL STRIP FOOTING) IS REQUIRED TO SUPPORT THE BASE OF THE METAL ARCH FORM.

1 • THE CONSTRUCTION OF THE REINFORCED SOIL ARCH FOR THE STRUCTURE REQUIRES THE USE OF AN ARCH SHAPED METAL FORM (TYPICALLY CORRUGATED STEEL PIPE, STRUCTURAL PLATE, DEEP OR ULTRADEEP STRUCTURAL PLATE) TO PRIMARILY AID IN THE CONSTRUCTION OF THE SOIL ARCH, BUT ALSO TO PROVIDE CONFINEMENT FOR THE SOIL AND TO PREVENT RAVELING OF THE SOIL FOLLOWING CONSTRUCTION. THE METAL FORM IS USED PRIMARILY FOR THE PURPOSE OF CONSTRUCTING THE SOIL ARCH AND IS A SECONDARY LOAD CARRYING ELEMENT OF THE STRUCTURE.

- FOR CLARIFICATION PURPOSES, THE PATENT DOES NOT INCLUDE GRS TECHNOLOGY. ADDITIONALLY, THE PATENT DOES NOT INCLUDE THE DESIGN AND CONSTRUCTION OF THE GRS FACING DETAILS (INCLUDING WELDED WIRE MESH FORMS) FOR RETAINED WALLS OR REINFORCED SOIL SLOPES AT THE INLET AND OUTLET ENDS OF THE STRUCTURE, OR OTHER SUCH DETAILS SHOWN ON THE DRAWINGS.

1.2 **INTENDED STRUCTURE USEAGE:** THE GRS ARCH™ STRUCTURE IS A MINISTRY APPROVED ALTERNATIVE TO OTHER TYPES OF CONVENTIONAL BURIED OPEN BOTTOM CROSSING STRUCTURES IN USE THAT SPAN THE ENTIRE STREAM CHANNEL. THE STRUCTURE MAY BE CONSIDERED ON A FOREST SERVICE ROAD (FSR) FOR RECONSTRUCTED STREAM CHANNEL CROSSING INSTALLATIONS (TO REPLACE AN EXISTING OPEN OR CLOSED BOTTOM CULVERT), OR FOR NEW NATURAL STREAM CHANNEL CROSSING INSTALLATIONS WHERE IT IS PRACTICABLE TO CLEAR SPAN THE STREAM CHANNEL WHILE LIMITING DISTURBANCE TO THE CHANNEL BANKS, AS DEPICTED IN STD-C-050-04.

2. DEFINITIONS

2.1 **DESIGN ENGINEER:** A PROFESSIONAL GEOTECHNICAL ENGINEER REGISTERED TO PRACTICE IN THE PROVINCE OF BRITISH COLUMBIA, EXPERIENCED IN THE DESIGN OF FOUNDATIONS, RETAINING WALLS, MAJOR CULVERTS, AND GRS STRUCTURES, RESPONSIBLE FOR ALL ASPECTS OF THE DETAILED DESIGN OF THE STRUCTURE (AND ASSURANCE OF CONSTRUCTION) IN CONFORMANCE WITH THESE CONCEPTUAL STANDARD DRAWINGS.

1 2.2 **COORDINATING REGISTERED PROFESSIONAL (CRP):** THE DESIGN ENGINEER MAY ACT AS THE CRP FOR THE PROJECT IF REQUESTED BY THE MINISTRY ENGINEER. THE CRP IS RESPONSIBLE FOR PLANNING AND COORDINATING ALL THE PROFESSIONAL SERVICES FOR THE CROSSING PROJECT INCLUDING THE DESIGN, FIELD REVIEWS, RECORD DRAWINGS AND *CRP CROSSING ASSURANCE STATEMENT*. THE CRP MUST DIRECT THOSE ACTIVITIES WITH SUFFICIENT OVERSIGHT AND SUPERVISION SUCH THAT THEY CAN TAKE OVERALL RESPONSIBILITY AND ACCOUNTABILITY FOR THE CROSSING.

1 2.3 **PROFESSIONAL OF RECORD (POR):** THE DESIGN ENGINEER SHALL BE THE POR RESPONSIBLE FOR PREPARATION OF CONSTRUCTION DRAWINGS, COMPLETION OF FIELD REVIEWS DURING CONSTRUCTION, AND COMPLETION OF THE *PROFESSIONAL OF RECORD CROSSING ASSURANCE STATEMENT* INCLUDING PREPARATION OF RECORD DRAWINGS.

2.4 **MINISTRY ENGINEER:** A PROFESSIONAL ENGINEER DESIGNATED BY THE MINISTRY OF FORESTS, LANDS AND NATURAL RESOURCE OPERATIONS.

3. GENERAL

1 3.1 **DESIGN:** THE DESIGN ENGINEER WILL CARRY OUT THE DETAILED DESIGN OF THE STRUCTURE. THESE CONCEPTUAL STANDARD DRAWINGS ARE INTENDED TO PROVIDE THE BASIC ELEMENTS AND REQUIREMENTS FOR THE DETAILED DESIGN OF STRUCTURES WITH SPANS OF 8.3m OR LESS AS SHOWN ON STD-C-050-04, AND CONSTRUCTION OF HEADWALLS AND WINGWALLS THAT ARE LESS THAN 6m HIGH.

3.2 **DESIGN VARIATIONS:** VARIATIONS FROM THE STANDARD DRAWING REQUIREMENTS MAY BE ACCEPTABLE IN CERTAIN SPECIAL SITUATIONS. ALL SUCH VARIATIONS WILL BE DOCUMENTED AND REQUIRE APPROVAL FROM THE MINISTRY ENGINEER PRIOR TO COMPLETION OF FINAL DESIGN AND CONSTRUCTION.

1 3.3 **GEOTECHNICAL:** A GEOTECHNICAL FIELD ASSESSMENT IS REQUIRED TO DETERMINE THE LIKELY FOUNDATION CONDITIONS AND THE LOCATION OF POTENTIAL GRANULAR BORROW MATERIALS FOR THE CONSTRUCTION OF THE GRS COMPOSITE MASS AS WELL AS SOURCES OF RIPRAP FOR SCOUR PROTECTION AND OTHER ROCK NEEDED FOR STREAM CHANNEL RECONSTRUCTION AND FOUNDATION CONSTRUCTION, AS REQUIRED.

3.4 **HYDROLOGY:** EACH PROJECT SITE REQUIRES AN ANALYSIS OF FLUVIAL GEOMORPHOLOGY AND STREAM CHANNEL HYDROLOGY, WITH ESTIMATES OF DESIGN STREAM FLOWS AND SPECIFIC CRITERIA FOR SCOUR PROTECTION OF EACH INSTALLATION. THE DESIGN ENGINEER WILL ALSO CONSIDER IMPLICATIONS OF CLIMATE CHANGE FOR STRUCTURES INSTALLED ON PERMANENT TERM FSRS, AND WILL ASSESS INCREASED HYDROLOGICAL HAZARDS DUE TO PREDICTIONS OF MORE SEVERE RAINFALL INTENSITIES OR INCREASED FLOOD MAGNITUDE AND FREQUENCY OVER THE DESIGN SERVICE LIFE.

3.5 **TOPOGRAPHIC:** DETAILED TOPOGRAPHIC INFORMATION IS REQUIRED FOR ALL PROJECT SITES PRIOR TO DETAILED DESIGN.

3.6 **DESIGN DRAWINGS:** DETAILED DESIGN AND CONSTRUCTION DRAWINGS WILL GENERALLY CONSIST OF THE FOLLOWING DRAWING SET: (1) SITE CONDITIONS, SITE LOCATION, AND GENERAL NOTES; (2) SITE PLAN; (3) STRUCTURE PROFILE; (4) CROSS-SECTIONS AND DETAILS; (5) DEADMAN ANCHOR AND GEOTEXTILE FABRIC LAYOUT VIEWS AND DETAILS; (6) ELEVATION VIEWS FROM UPSTREAM AND DOWNSTREAM; (7) CONSTRUCTION GUIDELINES, AND NOTES FOR REQUIRED TOOLS AND EQUIPMENT AND LABOUR, AND MATERIAL ESTIMATES; (8) PHOTOS OF THE SITE; AND (9) EXAMPLE PHOTOS OF TYPICAL CONSTRUCTION PROCEDURES FOR A SIMILAR STRUCTURE INSTALLATION TO GUIDE CONSTRUCTION. ALL WORKING POINTS AND WORKING POINT ELEVATIONS NECESSARY FOR CONSTRUCTION WILL BE SHOWN ON THE DRAWINGS. ALL DIMENSIONS WILL BE IN METRIC. THE DESIGN DRAWINGS WILL CLEARLY SPECIFIY THE STRUCTURE NUMBER ASSIGNED BY THE MINISTRY ENGINEER.

3.7 **DESIGN DRAWING REQUIREMENTS:** THE DESIGN DRAWINGS MUST PORTRAY AND DESCRIBE ALL THE DRAWING REQUIREMENTS DESCRIBED IN SECTION 4.11.5 (MAJOR CULVERT DRAWING REQUIREMENTS) IN THE MINISTRY'S ENGINEERING MANUAL AVAILABLE AT: HTTP://WWW.FOR.GOV.BC.CA/HTH/ENGINEERING/DOCUMENTS/PUBLICATIONS_GUIDEBOOKS/MANUALS_STANDARDS/ENG-MANUAL.PDF

1 3.8 **ROAD PROFILE:** THE ROAD PROFILE WILL BE SHAPED TO SUIT THE CROSSING SITE AND ADJACENT ROAD REQUIREMENTS. THE DESIGN AND CONSTRUCTION OF THE ROAD PROFILE WILL ENSURE SUITABLE CONTROL OF ROAD SURFACE WATER RUNOFF. THE STRUCTURE WILL BE LOCATED AT CREST OF A VERTICAL CURVE OR ALONG SUSTAINED ROAD GRADE (GREATER THAN 1%) TO PREVENT THE PONDING OF ROAD SURFACE WATER ABOVE THE STRUCTURE AND MINIMIZE INFILTRATION OF SURFACE WATER INTO THE GRS COMPOSITE MASS. DO NOT LOCATE THE STRUCTURE IN THE BOTTOM OF SAG CURVES.

3.9 **VEHICLE OFF TRACKING:** WHERE REQUIRED, THE DESIGN ENGINEER WILL CONSIDER THE EFFECTS OF VEHICLE OFF TRACKING IN THE DESIGN OF THE HORIZONTAL ALIGNMENT AT THE STRUCTURE LOCATION (IN BOTH DIRECTIONS). THE DESIGN ENGINEER WILL OBTAIN THE VEHICLE OFF TRACKING DESIGN CRITERIA FROM THE MINISTRY ENGINEER.

1 3.10 **SEDIMENTATION CONTROL DURING CONSTRUCTION:** THE DESIGN WILL INCLUDE REQUIREMENTS FOR SEDIMENTATION CONTROL DURING CONSTRUCTION TO PROTECT THE ENVIRONMENT.

1 3.11 **CONSTRUCTION GUIDELINES:** THE DESIGN WILL INCLUDE CONSTRUCTION GUIDELINES THAT DETAIL THE REQUIREMENTS AND SEQUENCE OF CONSTRUCTION ACTIVITIES REQUIRED FOR COMPLETING THE STRUCTURE.

3.12 **REQUIRED TOOLS AND EQUIPMENT:** THE DESIGN DRAWINGS WILL INCLUDE A DETAILED LIST OF REQUIRED TOOLS, EQUIPMENT AND LABOUR TO CONSTRUCT THE STRUCTURE TO MINIMIZE THE POTENTIAL FOR CONSTRUCTION DELAYS AND INCREASED CONSTRUCTION COSTS.

3.13 **FISH PASSAGE**: ALL LEGISLATIVE REQUIREMENTS TO PROTECT FISH AND FISH HABITAT, AND TO PROVIDE FOR FISH PASSAGE, MUST BE MET.

4. DESIGN

4.1 **DESIGN SERVICE LIFE:** THE DESIGN DRAWINGS WILL CLEARLY SPECIFY THE DESIGN SERVICE LIFE OF THE STRUCTURE.

- MINIMUM DESIGN SERVICE LIFE OF "PERMANENT TERM" STRUCTURES (I.E., IN SERVICE FOR OVER 15 YEARS) IS 45 YEARS, OR GREATER AS REQUIRED BY THE MINISTRY ENGINEER.

- MINIMUM DESIGN SERVICE LIFE OF TEMPORARY TERM STRUCTURES (I.E., IN SERVICE FOR UP TO 15 YEARS) IS 25 YEARS.

1 4.2 **DESIGN VEHICLES:** THE DESIGN DRAWINGS WILL CLEARLY SPECIFY THE DESIGN VEHICLE THAT WAS USED FOR THE STRUCTURE DESIGN.

- REFER TO MINISTRY STANDARD BRIDGE DRAWINGS FOR STANDARD DESIGN VEHICLES.

- **MINIMUM** DESIGN VEHICLE LOADING SHALL BE BCL-625.

- **MAXIMUM** DESIGN VEHICLE LOADING SHALL BE BCFS L-100.

- HEAVIER DESIGN VEHICLE LOADING FOR BCFS L-150 OR BCFS L-165 CAN BE CONSIDERED PROVIDED THIS IS SUPPORTED AND VALIDATED BY FINITE DIFFERENCE OR FINITE ELEMENT ANALYSIS.

1 4.3 **DESIGN APPROACH:** THE PROCEDURES FOR DESIGN OF A GRS COMPOSITE MASS (FOR SPANS 8.3m OR LESS) TO RESULT IN A REINFORCED SOIL ARCH INCLUDE BOTH LIMIT EQUILIBRIUM AND LIMIT STATES DESIGN APPROACHES WHICH HAVE BEEN SHOWN TO BE CONSERVATIVE BASED ON THE ANALYSIS OF 6.6m, 8.3m AND LARGER SPAN STRUCTURES USING FINITE DIFFERENCE AND FINITE ELEMENT ANALYSIS. THE INTERNAL STRENGTH OF THE (1) GRS COMPOSITE MASS COMPONENT OF THE REINFORCED SOIL ARCH, AND (2) GRS WALLS OR GRS REINFORCED SOIL SLOPES AT THE INLET AND OUTLET ENDS OF THE STRUCTURE, IS CALCULATED BASED ON CHAPTER 4 OF "GEOSYNTHETIC REINFORCED SOIL INTEGRATED BRIDGE SYSTEM INTERIM IMPLEMENTATION GUIDE" PUBLICATION NO. FHWA-HRT-11-026, DATED JANUARY 2011.

4.4 **DESIGN SPANS:** DESIGN SPAN AND RISE WILL BE SELECTED TO SUIT THE FLUVIAL GEOMORPHOLOGY AND HYDROLOGY OF THE STREAM. IF THE STRUCTURE IS NOT LOCATED AT A STREAM CHANNEL, THE SPAN AND RISE OF THE STRUCTURE WILL BE SELECTED BASED ON OTHER CRITERIA UNIQUE TO THE SPECIFIC APPLICATION.

1 - PROPOSED STRUCTURE SPANS CAPTURED BY THESE DRAWINGS AND SPECIFICATIONS ARE LIMITED TO 8.3m OR LESS.

4.5 **SEISMIC DESIGN:** SEISMIC DESIGN NOT REQUIRED UNLESS OTHERWISE SPECIFIED.

4.6 **DESIGN OF FOUNDATIONS:** DEPENDING ON STREAM CHANNEL HYDROLOGY, NATURAL SOIL CONDITIONS AND OTHER SITE SPECIFIC CONSIDERATIONS, THE DESIGN ENGINEER WILL DETERMINE THE REQUIREMENTS OF FOUNDATION PREPARATION FOR THE GRS COMPOSITE MASS. TYPICALLY, THIS WILL REQUIRE SUB-EXCAVATING UNSUITABLE SOILS TO A SPECIFIED DEPTH AND BACKFILLING WITH A DESIGNED ROCK FILL TO THE UNDERSIDE OF THE GRS COMPOSITE MASS AS SHOWN ON STD-C-050-04. THE ROCK FILL WILL BE COMPRISED OF DURABLE AND APPROPRIATELY SIZED AND SHAPED ROCK WITH THICKNESS AND WIDTH DIMENSIONS SPECIFIED ON THE DESIGN DRAWINGS.

4.7 **DESIGN OF SCOUR PROTECTION:** SCOUR OR UNDERMINING OF THE FOUNDATIONS OF THE GRS COMPOSITE MASS IS A KEY DESIGN CONSIDERATION. SECURITY AGAINST SCOUR FAILURE WILL BE BUILT INTO THE DESIGN OF THE FOUNDATIONS (E.G., EMBEDDING THE FOUNDATIONS BELOW THE ANTICIPATED SCOUR DEPTH LEVEL OR OTHER SUITABLE MEASURE). THE DESIGN WILL ALSO PROVIDE FOR PLACEMENT OF RIPRAP SCOUR PROTECTION AGAINST (1) THE FACING OF THE INLET AND OUTLET ENDS OF THE STRUCTURE TO AN APPROPRIATE CONTINGENCY ELEVATION ABOVE THE DESIGN HIGH WATER LEVEL, AND (2) THE INTERIOR SIDES OF THE METAL ARCH FORM ALONG THE BASE. THE MINIMUM CONTINGENCY ELEVATION ABOVE THE DESIGN HIGH WATER LEVEL IS 0.5m AND 0.3m, AT THE UPSTREAM AND DOWNSTREAM ENDS, RESPECTIVELY. RIPRAP CAN BE DESIGNED IN ACCORDANCE WITH THE "FOREST SERVICE BRIDGE DESIGN AND CONSTRUCTION MANUAL" OR OTHER SIMILAR APPROPRIATE REFERENCE FOR DESIGN OF RIPRAP.

4.8 **DESIGN OF RECONSTRUCTED STREAM CHANNEL INSTALLATIONS:** FOR RECONSTRUCTED STREAM CHANNEL INSTALLATIONS (TO REPLACE AN EXISTING CULVERT), THE SPAN OF THE ARCH FORM IS TO BE TYPICALLY A MINIMUM OF 20 PERCENT MORE THAN THE NATURAL, REPRESENTATIVE STREAM CHANNEL WIDTH (SHOWN ON STD_C_050_04) AS DETERMINED BY AN ASSESSMENT OF THE STREAM CHANNEL UPSTREAM AND DOWNSTREAM OF THE CROSSING SITE, WHERE APPLICABLE. THE DESIGN OF THE RECONSTRUCTED STREAM CHANNEL BED WITHIN THE INTERIOR OF THE METAL ARCH FORM WILL INCLUDE A DESIGNED SUBSTRATE COMPRISED OF DURABLE AND APPROPRIATELY SIZED AND SHAPED ROCK (WITH VOIDS IN-FILLED WITH SAND AND GRAVEL) WITH THICKNESS AND WIDTH DIMENSIONS SPECIFIED ON THE DESIGN DRAWINGS. THE DESIGN DRAWINGS WILL SPECIFY THE CONSTRUCTION PROCEDURES (INCLUDING COMPACTION) TO RECONSTRUCT THE STREAM CHANNEL.

- THE DESIGN WIDTH OF THE RECONSTRUCTED STREAM CHANNEL WILL CONSIDER THE REQUIREMENT FOR RIPRAP PLACED AGAINST THE INTERIOR SIDES OF THE METAL ARCH FORM.

1 4.9 **DESIGN OF GRS COMPOSITE MASS:** THE DESIGN ENGINEER WILL SPECIFY AND APPROVE ALL BACKFILL SOILS USED TO BUILD THE GRS COMPOSITE MASS, INCLUDING THE DEGREE OF SOIL COMPACTION REQUIRED AND COMPACTION PROCEDURES. ONLY NON FROST SUSCEPTIBLE, GRANULAR AND FREE DRAINING SOILS WILL BE USED TO BUILD THE GRS COMPOSITE MASS, COMPACTED AS SPECIFIED AND IN LIFT THICKNESSES DETERMINED BY THE GEOTEXTILE FABRIC SPACING SHOWN ON THE DESIGN DRAWINGS. PROVIDE FOR ADEQUATE DRAINAGE OF THE GRS COMPOSITE MASS. THE DESIGN WILL INCLUDE MEASURES TO PREVENT THE REINFORCED SOIL ZONE BACKFILL FROM MIGRATING AND ESCAPING THROUGH ANY VOIDS OR GAPS IN THE FACING ELEMENTS.

- THE MAXIMUM VERTICAL SPACING OF LAYERED GEOTEXTILE SOIL REINFORCEMENT WILL BE SHOWN ON THE DESIGN DRAWNGS AND WILL NOT EXCEED 0.3m .

- EXCEPT AS NOTED, ONLY WOVEN GEOTEXTILE FABRIC WILL BE USED AS REINFORCEMENT TO CONSTRUCT THE GRS COMPOSITE MASS. HOWEVER, DEPENDING UPON DETAILED SITE SPECIFIC CONSIDERATIONS AND IF SPECIFIED BY THE DESIGN ENGINEER, THE BOTTOM TWO LAYERS OF GEOTEXTILE FABRIC REINFORCEMENT, AS WELL AS GEOTEXTILE FABRIC REQUIRED FOR SEPARATION AND REINFORCEMENT IN FOUNDATION PREPARATION MAY BE NON-WOVEN.

1 - FREEZING OF SATURATED BACKFILL SOILS ADJACENT TO THE METAL ARCH FORM CAN RESULT IN SOIL EXPANSION AND FORCES IN THE ANCHORS WHICH EXCEED THE CAPACITY OF THE BARS OR THE CONNECTION BETWEEN THE ANCHOR BARS AND THE METAL ARCH FORM. ACCORDINGLY IN ADDITION TO THE REQUIRED CONTROL OF ROAD SURFACE RUNOFF WATER BY PROPER CONSTRUCTION OF THE ROAD PROFILE (SEE CLAUSE 3.8) TO MINIMIZE SURFACE WATER INFILTRATION INTO THE BACKFILL SOILS, THE DESIGN MUST INCLUDE PROVISIONS TO PRECLUDE POTENTIAL ADVERSE EFFECTS ASSOCIATED WITH THE FREEZING OF SATURATED SOILS ADJACENT TO THE METAL ARCH FORM, INCLUDING BUT NOT LIMITED TO SPECIFYING SUITABLE FREE-DRAINING GRANULAR BACKFILL SOILS AND INCORPORATING ADEQUATE DRAINAGE SYSTEMS TO PREVENT SATURATION OF THE BACKFILL.

CONCEPT DRAWINGS ONLY - NOT FOR CONSTRUCTION

ASSUME NOT TO SCALE

Province of British Columbia
MINISTRY OF FOREST, LANDS AND NATURAL RESOURCE OPERATIONS
ENGINEERING BRANCH

SCALE AS SHOWN

Designed CVB Date JULY2011
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Rev	Date	DESCRIPTION	Init	
1	June 2015	Text Edits	HM	

REVISIONS

STANDARD BRIDGE DRAWING

Terraspan® GRS Arch™ Structure–Conceptual Only

General Notes – Sheet 1

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DATE June 2015
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DRAWING No. STD–C–050–01 1

CANCEL PRINTS BEARING PREVIOUS NUMBER