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A risk assessment methodology to evaluate the risk failure of managed aquifer recharge in the Mediterranean Basin

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S1. LITERARURE REVIEW OF MANAGED AQUIFER RECHARGE FAILURES

CASE	RECHARGE TYPE	PLACE & TIME	DURATION OF THE PROJECT	MAIN PROBLEMS	REFERENCE
WATER FACTORY 21, COASTAL BARRIER SEAWATER INTRUSION	DEEP WELLS	ORANGE COUNTY (USA), 1977	4 YEARS	PROBLEMS - MICROBIOLOGICAL, METEOROLOGYCAL (EXCESS OF RAIN DIMINISHES THE AMOUNT OF WATER INJECTED), DESIGN AND CONSTRUCTION COSTS (16 MILLION $), OPERATION COSTS (2 MILION $ A YEAR), CLOGGING, WASTEWATER TREATMENT PLANT FAILURE, SALINITY/SODICITY (WATER INTRUSION), GEOLOGIGAL HETEROGENEICITY (DIFFERENT GEOLOGICAL MATERIAL LAYERS PRESENT), NOT SHALLOW AQUIFER OR HIGH THICKNESS (THE WELLS ARE REALLY DEEP 850 - 1150 FEET)	(ASANO, 1985)
OPERATIONS AT THE CEDAR CREEK WASTEWATER RECLAMATION-RECHARGE FACILITIES	DEEP WELLS	NASSAU COUNTY, NEW YORK, (1979)	3 YEARS (4 INCLUDING CONSTRUCTION)	PROBLEMS - DESIGN AND CONSTRUCTION COSTS (22 MILLION DOLLARS), CIVIL WORK FAILURES “VERY LIKELY” (OTHERS - UNDERDRAIN SYSTEMS, DUAL-MEDIA FILTER SYSTEM, CARBON ADSORVERS, MECHANICAL/ELECTRONIC PROBLEMS), OPERATIONAL COSTS (8 MILLION DOLARS), WASTEWATER TREATMENT PLANT FAILURE	(ASANO, 1985)
PROPOSED GROUNDWATER RECHARGE	DEEP WELLS	EL PASO, TEXAS (1985)	UNKNOWN	PROBLEMS - CONSTRUCTION COST (OVER 22 MILLION DOLLARS), NUTRIENTS (NITROGEN AND PHOSPORUS), SALINITY AND SODICITY, WASTEWATER TREATMENT PLANT FAILURE, SUSPENDED SOLIDS, GAS GENERATION (PHYSICIAL MOTIVES AND BAD DESIGN)	(ASANO, 1985)
GROUNDWATER RECHARGE FOR WASTEWATER REUSE IN THE DAN REGION PROJECT	INFILTRATION BASINS / SPREADING BASINS	ISRAEL, (1977)	5 YEARS	PROBLEMS - LAND USE (30 HA), LOW INFILTRATION RATES, CLIMATIC CONDITIONS, AND THE FREQUENCY OF BASIN CLEANING, SALINITY, NUTRIENTS (N AND P HIGHER IN WINTER), SUSPENDED SOLIDS (HIGHER IN WINTER), ORGANANIC CHEMICAL COMPOUNDS, WASTEWATER TREATMENT PLANT FAILURE, GEOLOGIGAL HETEROGENEICITY (DIFFERENT GEOLOGICAL MATERIAL LAYERS PRESENT), TRACE ELEMENTS (MAINLY METALS, BUT ALSO MANGANESE AND POTASSIUM)	(ASANO, 1985)
SOIL DEPOSITION OF TRACE METALS DURING GROUNDWATER RECHARGE USING SURFACE SPREADING	SURFACE SPREADING	CALIFORNIA (USA)	20 YEARS	PROBLEMS - SALINITY AND SODICITY, SUSPENDED SOLIDS, TRACE ELEMENTS (OTHERS BUT MAINLY METALS), CLOGGING (NOT SPECIFIED), ORGANIC CHEMICALS, WATER SCARCITY (CLIMATE)	(ASANO, 1985)
ISSUES IN ARTIFICIAL RECHARGE	GENERAL	NA	NA	PROBLEMS - LONG TIME, CHEMICAL QUALITY ISSUES NOT A PROBLEM – HAS GOOD SOCIAL ACCEPTANCE	(BOUWER, 1996)

CASE	RECHARGE TYPE	PLACE & TIME	DURATION OF THE PROJECT	MAIN PROBLEMS	REFERENCE
ISSUES IN ARTIFICIAL RECHARGE	INFILTRATION BASINS	NA	NA	PROBLEMS – LAND USE, WATER QUALITY, CLOGGING, SUSPENDED SOLIDS CONTENT, ORGANIC COMPOUNDS, FLOODING, DRYING, NUTRIENTS (NITROGEN MAINY), BAD SOIL INFILTRATION RATE AND COMPACTION	(BOUWER, 1996)
ISSUES IN ARTIFICIAL RECHARGE	DEEP WELLS	NA	NA	PROBLEMS – MAIN PROBLEM IS CLOGGING, SUSPENDED SOLIDS, MICROORGANISMS, NUTRIENTS (N AND P), DESIGN AND CONSTRUCTION COSTS, CORROSION NOT A PROBLEM – CAN BE DONE IN ZONES WHERE PERMEABLE SOILS ARE NOT AVAILABLE	(BOUWER, 1996)
ISSUES IN ARTIFICIAL RECHARGE	VADOSE ZONE WELLS	NA	NA	PROBLEMS – CLOGGING, SUSPENDED SOLIDS, NUTRIENTS, MICROORGANISMS, ORGANIC COMPOUNDS, LOW INFILTRATION RATES NOT A PROBLEM - CHEAPER	(BOUWER, 1996)
ISSUES IN ARTIFICIAL RECHARGE	SEEPAGE TRENCHES	NA	NA	PROBLEMS – SUSPENDED SOLIDS ARE USUALLY A PROBLEM, NOT A PROBLEM - CHEAPER	(BOUWER, 1996)
ARTIFICIAL RECHARGE OF GROUNDWATER: HYDROGEOLOGY AND ENGINEERING	SURFACE INFILTRATION	NA	NA	PROBLEMS – FLOOD DANGER, CIVIL WORK FAILURES (OTHERS AND SLOPE), LAND USE, WATER QUALITY PROBLEMS, SUSPENDED SOLIDS, CLOGGING (BIOLOGICAL, MINERAL AND SEDIMENTAL), GAS FORMATION (BACTERIAL MAINLY BUT THER TYPES ARE ALSO QUITE TYPICAL), NUTRIENTS, ORGANIC COMPOUNDS, RISK OF LOW INFILTRATION RATE, CONTAMINANT SPREADING	(BOUWER, 2002A)
ARTIFICIAL RECHARGE OF GROUNDWATER: HYDROGEOLOGY AND ENGINEERING	VADOSE-ZONE INFILTRATION	NA	NA	PROBLEMS – VERY LIKELY RISK OF INSUFICIENT SOIL INFILTRATION RATE, LAND USE, PIPELINE FAILURE, GAS ACCUMULATION (PHYSICAL), PIPE FAILURE, MAINLY DISADVANTAGE IS CLOGGING (BIOLOGICAL AND SEDIMENTAL), SUSPENDED SOLIDS CONTENT, NOT PROBLEM - CHEAPER	(BOUWER, 2002A)
ARTIFICIAL RECHARGE OF GROUNDWATER: HYDROGEOLOGY AND ENGINEERING	WELLS	NA	NA	PROBLEMS – COMPACTION, CLOGGING (MOST TYPICALL PROBLEM, DUE TO SEDIMENTS BUT ALSO OTHER REASONS LIKE BACTERIA OR PRECIPITATION), WATER QUALITY, NUTRIENTS, SALINITY, MICROBIOLOGICAL PROBLEMS, NOT PROBLEM – LAND USE, INFILTRATION RATE	(BOUWER, 2002A)
ARTIFICIAL RECHARGE OF GROUNDWATER: HYDROGEOLOGY AND ENGINEERING	GENERAL ARTIFICIAL RECHAR	NA	NA	THE MAIN ISSUE IN ARTIFICIAL RECHARGE IS CLOGGING, AVAILABILITY OF WATER RESOURCES IS ALSO A PROBLEM WITH CLIMATIC ISSUES, SOCIAL COSTS, ENVIRONMENTAL COSTS, LAND USE, CIVIL WORK PROBLEMS (IN GENERAL, CORROSION),	(BOUWER, 2002A)

CASE	RECHARGE TYPE	PLACE & TIME	DURATION OF THE PROJECT	MAIN PROBLEMS	REFERENCE
	GE SYSTEMS				
ARTIFICIAL RECHARGE OF AQUIFERS	INFILTRATION BASINS AND CANALS	SAN JUAN RIVER BASIN (ARGENTINA)	NA	PROBLEMS – SEDIMENTATION OF FINE MATERIAL (CLOGGING, TURBIDITY, ETC.), FLOODING RISK (THE FLOODS MAY INTERFERE WITH THE INFILTRATION BASIN), DEPOSITION PROBLEMS, CORROSION, EROSION PROBLEMS, CIVIL DAMAGE (OTHERS), VANDALISM PROBLEMS (MAY BE CONSIDERED AS TERRORISM?), DROUGH PROBLEMS, DURING DROUGH STAGES THERE MAY BE A SHORTAGE OF WATER RESOURCES TO FEED THE RECHARGE, LACK OF INCENTIVES (LEGISLATIVE AND ECONOMICAL) FOR MAINTENANCE, LACK OF ENOUGH WATER TO HAVE AN ECONOMICALLY FEASIBLE RECHARGE, PROBLEM WITH NUTRIENTS (N AND P), RISK OF AQUIFER DISSOLUTION, LEGISLATION PROBLEMS (OTHERS, RELATED TO ENVIRONMENTAL IMPACT OF THE LANDSCAPE), HIGH THICKNESS AND NOT SHALLOW AQUIFER NOT PROBLEM – LOW MAINTENANCE COSTS, LOW DESIGN AND CONSTRUCTION COSTS, USUALLY THE TECHNICAL KNOWLEDGE OF THIS TECHNOLOGY IS HIGH,	(NATIONS AND PROGRAMME, 2011))
INVESTIGATING THE CAUSES OF WATER-WELL FAILURE IN THE GAOTLHOBOGWE WELLFIELD	DEEP WELLS	SOUTHEAST BOTSWANA	8 YEARS	PROBLEMS – WATER QUALITY (METALS, SALINITY/SODICITY, NITROGEN, PHOSPHORUS, ETC.), LOW QUANTITY OF WATER RESOURCES, PROBLEMS WITH INFILTRATION RATE, RISK OF LOW WATER STORAGE, CHEMICAL CLOGGING (PRECIPITATION OF CALCITE DUE TO WATER MIXTURE), PROBLEMS WITH THE DESIGN AND OPERATION OF THE WELLS	(CHAOKA ET AL., 2006)
AQUIFER STORAGE AND RECOVERY	DEEP WELLS	CALIFORNIA (USA)	NA	PROBLEMS – WATER QUALITY (SUSPENDED SOLIDS, SALINITY/SODICITY, SOCIAL UNACCEPTANCE (TASTE IN WATER), LEGAL CONSTRAINTS (NOT ACCOMPLISHING DRINKING STANDARDS) , MOVILISATION OF TRACE ELEMENTS, PRECIPITATION (CHEMICAL CLOGGING), CLOGGING (SEDIMENT AND MICROBIOLOGICAL), IN GENERAL CLOGGING IS THE MOST TYPICALL PROBLEM, INFILTRATION PROBLEMS, CIVIL WORK FAILURES (LIQUEFACTION), NATURAL HAZARDS (EARTHQUAKE), TERRORISTS ATTACKS	("USGS CALIFORNIA WATER SCIENCE CENTER," 2015)
TROUBLESHOOTING WATER WELL PROBLEMS	DEEP WELLS	NA	NA	PROBLEMS – IMPROPER WELL DESIGN AND OPERATION, INCOMPLETE WELL DEVELOPMENT, BOREHOLE STABILITY PROBLEMS, INCRUSTATION BUILD-UP (CLOGGING DUE TO CHEMICAL ISSUES WITH WATER), BIOFOULING CLOGGING DUE TO MICROBIOLOGICAL ISSUES), CORROSION, AQUIFER PROBLEMS, OVER PUMPING (SEDIMENT PARTICLE MOVING, SEDIMENTATION, EROSION, COMPACTION), NUTRIENT PROBLEMS (N AND P), GAS GENERATION (BACTERIAL AND	(GOVERNMENT OF ALBERTA, N.D.)

CASE	RECHARGE TYPE	PLACE & TIME	DURATION OF THE PROJECT	MAIN PROBLEMS	REFERENCE
				INAPROPIATE DESIGN), LACK OF RECHARGE, CLIMATE ISSUES, DROUGH PERIODS, CIVIL WORK FAILURE (PIPES BREAKAGE AND OTHERS), LOW INFILTRATION, WATER QUALITY ISSUES (METALS, NUTRIENTS AND ORGANIC COMPOUNDS)	
AUSTRALIAN GUIDELINES FOR WATER RECYCLING: MANAGED AQUIFER RECHARGE	DEEP WELLS	AUSTRALIA	NA	NOT PROBLEM - LOW CAPITAL COSTS (MANAGED RECHARGE IS OFTEN THE MOST ECONOMIC FORM OF NEW WATER SUPPLY), NO EVAPORATION LOSS, NOT ALGAE OR MOSQUITOES (UNLIKE DAMS), NO LOSS OF PRIME VALLEY FLOOR LAND (EROSION), ABILITY TO USE SALINE AQUIFERS THAT COULD NOT BE DIRECTLY USED FOR SUPPLIES, POTENTIAL LOCATION CLOSE TO NEW WATER SOURCES, AND WHERE DEMAND FOR WATER IS HIGH, AQUIFERS PROVIDING TREATMENT AS WELL AS STORAGE, LOW GREENHOUSE GAS EMISSIONS COMPARED TO REMOTE PUMPED STORAGES, ABLE TO BE BUILT TO THE SIZE REQUIRED FOR INCREMENTAL GROWTH IN WATER DEMAND, PROVISION OF EMERGENCY AND STRATEGIC RESERVES, IMPROVED RELIABILITY OF EXISTING SUPPLIES, IMPROVED ENVIRONMENTAL FLOWS IN WATER SUPPLY CATCHMENTS FOR URBAN AREAS	(EPHC/NHMRC/NRMMC, 2008)
AUSTRALIAN GUIDELINES FOR WATER RECYCLING: MANAGED AQUIFER RECHARGE	GENERAL ARTIFICIAL RECHARGE SYSTEMS	AUSTRALIA	NA	DEEP WELLS – PREFERABLY USED WHEN THERE ARE CONFINED AQUIFERS OR SUPERFICIAL CLAY LEVELS, CAN WORK WITH LOW INFILTRATION RATE, LOW LAND USE/COST, EASE OF TRAFFIC ACCESS, COMPATIBILITY OF LAND USE, SUSPENDED SOLIDS AND NUTRIENTS USUALLY LEAD TO CLOGGING PROBLEMS INFILTRATION PONDS – PREFERED WHEN LAND COST/USE IS CHEAP GENERAL INFO - USUALLY ARTIFICIAL RECHARGE HAS GOOD SOCIAL ACCEPTANCE AND SUFICIENT RESIDENCE TIMES FOR WATER, THIS RESIDENCE TIME IMPLIES LESS TREATMENT FOR THE WATER AND LESS RISK FOR PATHOGENS	(EPHC/NHMRC/NRMMC, 2008)
AUSTRALIAN GUIDELINES FOR WATER RECYCLING: MANAGED AQUIFER RECHARGE	GENERAL ARTIFICIAL RECHARGE SYSTEMS	AUSTRALIA	NA	GENERAL INFO – ARTIFIAL RECHARGE DEPENDS MAINLY ON THE AVAILABILITY OF APROPIATE AQUIFERS, SUFFICIENT VOLUMES OF WATER ARE NEEDED TO JUSTIFY THE COSTS OF THE PROJECT, PLACES WITH SURFACE AQUIFERS CAUSE STRUCTURAL PROBLEMS, SALINISATION AND WATERLOGGING.	(EPHC/NHMRC/NRMMC, 2008)
AUSTRALIAN GUIDELINES FOR WATER RECYCLING: MANAGED AQUIFER RECHARGE	DEEP WELLS	NORTHERN ADELAIDE PLAINS (AUSTRALIA)	NA	PROBLEMS – SALINITY, AQUIFER HETEROGENITY, WATER MIXTURE, NEED TO HAVE A WATER TREATMENT PLANT (DESIGN AND CONSTRUCTION COSTS, OPERATIONAL COSTS) NOT PROBLEMS – MEET DRINKIG WATER REQUERIMENTS	(EPHC/NHMRC/NRMMC, 2008)

CASE	RECHARGE TYPE	PLACE & TIME	DURATION OF THE PROJECT	MAIN PROBLEMS	REFERENCE
AUSTRALIAN GUIDELINES FOR WATER RECYCLING: MANAGED AQUIFER RECHARGE	GENERAL ARTIFICIAL RECHARGE SYSTEMS	AUSTRALIA	NA	PROBLEMS – PATHOGENS, INORGANIC CHEMICALS, SALINITY AND SODICITY, NUTRIENTS, ORGANIC CHEMICALS, TURBIDITY AND PARTICULATES, RADIONUCLIDES, PRESSURE/FLOW RATES/VOLUMES/LEVELS OF WATER, CONTAMINANT MIGRATION IN FRACTURED AND CARSTIC AQUIFERS, AQUIFER DISSOLUTION, WELL STABILITY, IMPACT ON GROUNDWATER ECOSYSTEMS, GREENHOUSE GASES GENERATION (MICROBIOLOGICAL ISSUES)	(EPHC/NHMRC/NRMMC, 2008)
AUSTRALIAN GUIDELINES FOR WATER RECYCLING: MANAGED AQUIFER RECHARGE	GENERAL ARTIFICIAL RECHARGE SYSTEMS	AUSTRALIA	NA	PROBLEMS – INCREASE IRON, MANGANESE, ARSENIC, TRACE SPECIES AND HYDROGEN SULFIDE, SODICITY/SALINITY PROBEMS, NTRIENT ISSUES,	(EPHC/NHMRC/NRMMC, 2008)
MOBILIZATION OF ARSENIC AND OTHER TRACE ELEMENTS DURING AQUIFER STORAGE AND RECOVERY, SOUTHWEST FLORIDA	DEEP WELLS	FLORIDA (USA)	NA	PROBLEMS – ARSENIC, MANGANESE, URANIUM (RADIONUCLIDES), ORGANIC COMPOUNDS, WATER RESIDENCE TIME, AQUIFER AND INPUT WATER CHEMISTRY PROBLEMS (DO, PH, ETC.), AQUIFER MATRIX CHEMISTRY/MINERALOGY, SITE SPECIFIC HIDROGEOLOGY/HIDROCHEMISTRY, WATER MIXTURE	(AIKEN AND KUNIANSKY, 2002)
AUSTRALIAN GUIDELINES FOR WATER RECYCLING: MANAGED AQUIFER RECHARGE	GENERAL ARTIFICIAL RECHARGE SYSTEMS	AUSTRALIA	NA	GENERAL INFO – ABOUT CLOGGING THERE'S INFO FROM 14 INJECTION PLACES THAT SUFERED CLOGGING PROBLEMS. FROM THE 14 SITES, 8 WERE BIOLOGICAL CLOGGING, 9 PHYSICAL CLOGGING AND 1 WAS CHEMICAL CLOGGING (IN SOME CASES THERE WAS A MIXTURE BETWEEN TWO TYUPES OF CLOGGING)	(EPHC/NHMRC/NRMMC, 2008)
SOURCES OF HIGH-CHLORIDE WATER TO WELLS, EASTERN SAN JOAQUIN GROUND-WATER SUBBASIN, CALIFORNIA	DEEP WELLS	CALIFORNIA (USA)	NA	PROBLEMS – SALINITY/SODICITY, CHLORIDE, METALS (ARSENIC, MANGANESE, ETC.), NUTRIENTS (NITRATES), WATER MIXTURE, WATER EVAPORATION	(AIKEN AND KUNIANSKY, 2002)
AQUIFER STORAGE AND RECOVERY FOR THE CITY OF ROSEVILLE: A CONJUNCTIVE USE PILOT PROJECT	DEEP WELLS	CALIFORNIA (USA)	NA	PROBLEMS – ORGANIC CHEMICALS (THM, DBP), DESIGN AND CONSTRUCTION COSTS (PROJECTS OF WATER RECHARGE WITH A COST OF MORE THAN 215 MILLION $), LEGISLATION ISSUES (NATIONAL AND LACK OF COORDINATION), TRACE ELEMENTS (METALS), MECHANICAL COMPLICATIONS (CIVIL WORK FAILURE – OTHERS), SODICITY/SALINITY, MICROBIOLOGICAL ISSUES (LEGISLATION ABOUT BACTERIA INPUT IN THE RECHARGE WATER), WATER MIXTURE,	(AIKEN AND KUNIANSKY, 2002)

CASE	RECHARGE TYPE	PLACE & TIME	DURATION OF THE PROJECT	MAIN PROBLEMS	REFERENCE
				QUALITY ISSUES (IN GENERAL, IT DOESNN'T SPECIFY), AQUIFER THICKNESS AND AQUIFER DEPTH, WATER SCARCITY (DROUGHT) NOT PROBLEM – NATURAL ATENUATION,	
SAN GORGONIO PASS ARTIFICIAL RECHARGE INVESTIGATION	DEEP WELLS	CALIFORNIA (USA) 1997	6 YEARS	PROBLEMS – LOW INFILTRATION RATE, HIGH THICKNESS/NOT SHALLOW AQUIFER, NATURAL HAZARDS (EARTHQUAKES), NUTRIENTS (NITROGEN DUE TO WASTEWATER LEAKAGE)	(FLINT AND ELLETT, 2005)
THE EFFECTS OF ARTIFICIAL RECHARGE ON GROUNDWATER LEVELS AND WATER QUALITY IN THE WEST HYDROGEOLOGIC UNIT OF THE WARREN SUBBASIN, SAN BERNARDINO COUNTY, CALIFORNIA	DEEP WELLS	CALIFORNIA (USA) 2004	5 YEARS	PROBLEMS – LOW INFILTRATION RATE, RESIDENCE TIME, LAND USE, RISK OF NUTRIENT MOBILISATION, WATER LEVEL DECLINE, NUTRIENTS (NITROGEN), ORGANIC CHEMICALS, WATER SCARCITY (DROUGHTS AND RAINFALL PERIODICITY), EVAPORATION, SEDIMENTATION, EROSION, REGIONAL HYDROGEOLOGY WATER IMBALANCE, NO PROBLEM – NATURAL ATENUATION	(U.S. GEOLOGICAL SURVEY, 2013)
HYDRO-LOGIC EFFECTS OF ARTIFICIAL-RECHARGE EXPERIMENTS WITH RECLAIMED WATER AT EAST MEADOW, LONG ISLAND, NEW YORK	INFILTRATION BASINS	NEW YORK (USA) 1982	2 YEARS	PROBLEMS – LAND USE, GAS GENERATION (PHYSICAL MOTIVES AND BAD DESIGN), LOW INFILTRATION RATES, SUSPENDED SOLIDS, CLOGGING (PHYSICAL AND BIOLOGICAL), MECHANICAL FAILURES, PONDING (UNWANTED WATER ACCUMULATION), MICROBIOLOGICAL ISSUES, DEVELOPMENT OF INSECT POPULATIONS, WATER QUALITY ISSUES (MAINLY MICROBIOLOGICAL, NUTRIENTS AND MAYBE OTHER WATER CHEMICAL COMPOUNDS), SALINITY/SODICITY, METALS, SLOPE FACTOR ISSUES (MOUNDING), WATER MIXING, ORGANIC CHEMICALS (ORGANIC MATTER), INORGANIC CHEMICALS, INEFICIENT NATURAL ATTENUATION (DUE TO SHORT RESIDENCE TIME, NOT ENOUGH REACTION OF THE GEOLOGICAL MATERIALS OR DUE TO THE HIGH TREATMENT OF THE INJECTED WATER)	(SCHNEIDER ET AL., 1987)
HYDRO-LOGIC EFFECTS OF ARTIFICIAL-RECHARGE EXPERIMENTS WITH RECLAIMED WATER AT EAST MEADOW, LONG ISLAND, NEW YORK	DEEP WELLS	NEW YORK (USA) 1982	2 YEARS	PROBLEMS – SUSPENDED SOLIDS (TURBIDITY), CLOGGING (BACTERIAL, PHYSICAL AND CHEMICAL), METALS (IRON), SALINITY/SODICITY, LESS EFFICIENT TO MOVE LARGE QUANTITIES OF WATER THAN THE INFILTRATION BASINS, CLOGGING IS MORE A PROBLEM IN WELLS THAN IN BASINS, SLOPE FACTOR ISSUES (MOUNDING), INEFICIENT NATURAL ATTENUATION (DUE TO SHORT RESIDENCE TIME, NOT ENOUGH REACTION OF THE GEOLOGICAL	(SCHNEIDER ET AL., 1987)

CASE	RECHARGE TYPE	PLACE & TIME	DURATION OF THE PROJECT	MAIN PROBLEMS	REFERENCE
				MATERIALS OR DUE TO THE HIGH TREATMENT OF THE INJECTED WATER)	
THE ATLANTIS WATER RESOURCE MANAGEMENT SCHEME: 30 YEARS OF ARTIFICIAL GROUNDWATER RECHARGE	INFILTRATION BASINS	SOUTH AFRICA (1980)	30 YEARS	PROBLEMS – CLOGGING (PHYSICAL, BIOLOGICAL AND CHEMICAL), METAL CONTENT (IRON), NOT ENOUGH WATER QUANTITY, ORGANIC MATTER, LOW INFILTRATION RATE, HIGH MAINTENANCE COSTS, GROUNDWATER POLLUTION, APPEREANCE OF ALIEN VEGETAL SPECIES, MICROBIOLOGICAL ISSUES, LAND OWNERSHIP PROBLEMS (IS NOT UNDER THE SAME LEGAL MANAGEMENT THAN THE REST OF THE RECHARGE FACILITY) NOT PROBLEM – LOW SALINITY	(TREDOUX AND CAIN, 2010)
THE ATLANTIS WATER RESOURCE MANAGEMENT SCHEME: 30 YEARS OF ARTIFICIAL GROUNDWATER RECHARGE	DEEP WELLS	SOUTH AFRICA (1980)	30 YEARS	PROBLEMS – CLOGGING (PHYSICAL, BIOLOGICAL AND CHEMICAL), METAL CONTENT (IRON), NOT ENOUGH WATER QUANTITY, ORGANIC MATTER, LOW INFILTRATION RATE, HIGH MAINTENANCE COSTS, DROUGH CONDITIONS, OVERPUMPING WATER (IMBALANCE BETWEEN THE WATER INJECTION AND PUMPING), GAS GENERATION (DUE TO PHYSICAL PROPERTIES AND INEFICIENT DESIGN), GROUNDWATER POLLUTION, SALINITY/SODICITY PROBLEMS, MICROBIOLOGICAL ISSUES, LAND OWNERSHIP PROBLEMS (IS NOT UNDER THE SAME LEGAL MANAGEMENT THAN THE REST OF THE RECHARGE FACILITY)	(TREDOUX AND CAIN, 2010)
RECYCLING POLOKWANE'S TREATED WASTEWATER	INFILTRATION PONDS	SOUTH AFRICA	NA	PROBLEMS – HIGH THICKNESS AND NOT SHALLOW AQUIFER, EVAPORATION OF WATER (WATER LOSS), NUTRIENT PROBLEMS (MAINLY NITROGEN)	(TREDOUX AND CAIN, 2010)
SMALL-SCALE BOREHOLE INJECTION IN NAMAQUALAND	DEEP WELLS	SOUTH AFRICA (1999)	3 YEARS	PROBLEMS – LOW INFILTRATION RATE, SALINITY/SODICITY, CLOGGING (PHYSICAL)	(TREDOUX AND CAIN, 2010)
CALVINIA: TRIAL BOREHOLE INJECTION TESTS AND WATER QUALITY ASSESSMENT IN FRACTURED MUDSTONES	DEEP WELLS	SOUTH AFRICA	NA	PROBLEMS – LOW WATER STORAGE TIME (RESIDENCE TIME), HIGH WATER PH (WATER QUALITY PROBLEMS), HIGH FLUORIDE CONCENTRATIONS, HIGH ARSENIC CONCENTRATIONS, HIGH SULFATE CONCENTRATIONS, OXYGEN PENETRATION (REDOX PROCESSES), ENTRANCVE OF GAS FROM THE ATHMOSPHERE (DUE TO PHYSICAL MOTIVES AND BAD DESIGN).	(TREDOUX AND CAIN, 2010)
PRINCE ALBERT: BOREHOLE INJECTION FEASIBILITY STUDY IN FRACTURED SANDSTONES	DEEP WELLS	SOUTH AFRICA	NA	PROBLEMS – MICROBIOLOGICAL ISSUES, HIGH FLUORIDE CONCENTRATIONS, NUTRIENTS (MAINLY NITROGEN), CLOGGING (BIOLOGICAL AND CHEMICAL), IRON CONTENT, LOW QUANTITY WATER AVAILABLE (CLIMATE), LOW PERMEABILITY RATES,	(TREDOUX AND CAIN, 2010)

CASE	RECHARGE TYPE	PLACE & TIME	DURATION OF THE PROJECT	MAIN PROBLEMS	REFERENCE
BITOU MUNICIPALITY GROUNDWATER MANAGEMENT AND ARTIFICIAL RECHARGE FEASIBILITY STUDY	DEEP WELLS	SOUTH AFRICA	2 YEARS	PROBLEMS – WATER SCARCITY (WWTP FAILURE OR TOO LOW SUPPLY LIMIT), SALINITY/SODICITY, IRON CONTENT, AND ORGANIC MATTER, WATER MIXTURE (CHEMICAL REACTIONS), CLOGGING (CHEMICAL AND BIOLOGICAL), WATER IMBALANCE BETWEEN INJECTION AND WATER INPUT (NOT ENOUGH WATER FROM REGIONAL HYDROGEOLOGY), LEGAL CONSTRAINTS (OTHERS – ENVIRONMENTAL)	(TREDOUX AND CAIN, 2010)
ARTIFICIAL RECHARGE OF THE WINDHOEK AQUIFER, NAMIBIA: WATER QUALITY CONSIDERATIONS	DEEP WELLS	NAMIBIA	NA	PROBLEMS – SODICITY/SALINITY, HIGH SULFATE CONCENTRATIONS, HIGH IRON CONCENTRATIONS, PRESENCE OF A DISPOSAL SITE WHICH IS THE SOURCE OF ORGANIC POLLUTANTS INFILTRATION	(TREDOUX ET AL., 2009)
IN THE FACE OF CHANGING CLIMATE: GROUNDWATER DEVELOPMENT THROUGH ARTIFICIAL RECHARGE IN HARD ROCK TERRAIN OF KUMAUN LESSER HIMALAYA	INFILTRATION BASINS	KUMAUN LESSER HIMALAYA	NA	PROBLEMS - LOW CONDUCTIVITY OF THE WATER, FLOODS, DROUGHS, HIGH THICKNESS AND NOT SHALLOW AQUIFER, CIVIL WORK FAILURES (OTHERS – HIGH STEEP SLOPES), WATER SCARCITY (CLIMATE, DUE TO THE FACT THAT RAINFALL IS THE ONLY SOURCE OF WATER FOR THE RECHARGE)	(TRIPATHI, 2016)
ASSESSING RISK OF CLOGGING IN COMMUNITY SCALE MANAGED AQUIFER RECHARGE SITES FOR DRINKING WATER IN THE COASTAL PLAIN OF SOUTH-WEST BANGLADESH	INFILTRATION PONDS AND INFILTRATION WELLS	BANGLADESH	NA	PROBLEMS – LOW INFILTRATION RATE, CIVIL WORK FAILURE (OTHERS – MAINLY RELATED TO THE MINAROLOGY OF THE TERRAIN), HIGH TURBIDITY (SUSPENDED SOLIDS), HIGH SULFATES, HIGH NUTRIENTS (PHOSPHORUS MAINLY), MICROBIOLOGICAL ISSUES, CLOGGING (PHYSICAL TYPE MAINLY), ORGANIC MATTER CONTENT, FILTER EFFICIENCY ISSUES, RESIDENCE TIME, NUTRIENTS (NITROGEN), CLOGGING (BIOLOGICAL), AQUIFER HETEROGENEICITY (DIFFERENT GEOLOGICAL MATERIAL LAYERS ON THE AQUIFER), WATER MIXTURE, SALINITY/SODICITY ISSUES	(SULTANA AND AHMED, 2016)
INVESTIGATION OF RECHARGE DYNAMICS AND FLOW PATHS IN A FRACTURED CRYSTALLINE AQUIFER IN SEMI-ARID INDIA USING BOREHOLE LOGS: IMPLICATIONS FOR	PERCOLATION TANK	INDIA (HYDERABAD)	NA	PROBLEMS – GEOLOGIGAL HETEROGENEICITY (DIFFERENT GEOLOGICAL MATERIAL LAYERS PRESENT), LOW INFILTRATION RATE, FLOODS, DROUGHS, NOT SHALLOW AQUIFER/GEOLOGY THICKNESS, NOT ENOUGH WATER (CLIMATE), WATER MIXING	(ALAZARD ET AL., 2016)

CASE	RECHARGE TYPE	PLACE & TIME	DURATION OF THE PROJECT	MAIN PROBLEMS	REFERENCE
MANAGED AQUIFER RECHARGE					
IMPACT OF A STORM-WATER INFILTRATION BASIN ON THE RECHARGE DYNAMICS IN A HIGHLY PERMEABLE AQUIFER	INFILTRATION BASIN	ITALY	NA	PROBLEMS – LEGAL CONSTRAINTS, CLOGGING (PHYSICAL AND BIOLOGICAL), SUSPENDED SOLIDS, NOT PROBLEM – HIGH RECHARGE RATE (PRECIPITATION), HIGH AMOUNT OF WATER AVAILABLE, HIGH INFILTRATION RATE	(MASETTI ET AL., 2016)
AN INNOVATIVE ARTIFICIAL RECHARGE SYSTEM TO ENHANCE GROUNDWATER STORAGE IN BASALTIC TERRAIN: EXAMPLE FROM MAHARASHTRA, INDIA	RECHARGE SHAFTS AND SUBSURFACE DAMS	INDIA	NA	PROBLEM – LOW INFILTRATION RATE, EXCESIVE WITHDRAWAL, WATER IMBALANCE (INPUT/OUTPUT OF WATER), WATER SCARCITY (CLIMATE), DROUGHS, EROSION ISSUES, SUSPENDED SOLIDS	(BHUSARI ET AL., 2016)
INTEGRATED FRAMEWORKS FOR ASSESSING AND MANAGING HEALTH RISKS IN THE CONTEXT OF MANAGED AQUIFER RECHARGE WITH RIVER WATER	SURFACE WATER FROM A RIVER (INFILTRATION BASINS)	FINLAND	NA	PROBLEMS – MICROBIOLOGICAL ISSUES, NUTRIENTS, CONTAMINANTS (ORGANIC AND INORGANIC), LACK OF COORDINATION (POLITICAL CONCERNS), ECONOMIC COSTS (DESIGN/CONSTRUCTION AND OPERATION), ORGANIC MATTER, PERSISTENT ORGANIC POLUTANTS, LACK OF KNOWLEDGE, COST-BENEFIT IMBALACE RELATED TO OTHER WATER RESOURCES OPTIONS (WHICH WOULD BE BETTER OR CHEAPER),	(ASSMUTH ET AL., 2016)
THE EFFECTS OF ARTIficIAL RECHARGE OF GROUNDWATER ON CONTROLLING LAND SUBSIDENCE AND ITS IFLUENCE ON GROUNDWATER QUALITY AND AQUIFER ENERGY STORAGE IN SHANGHAI, CHINA	DEEP WELLS	CHINA	NA	PROBLEMS – SURFACE COVER OF HARD AND LOW INFILTRATION RATE GEOLOGICAL MATERIALS, COMPACTION, SUBSIDENCE ISSUES, GEOLOGICAL LAYERS OVERLAPPING (NOT A CONTINOUS AQUIFER BUT THE DISPOSITION OF DIFFERENT GEOLOGICAL MATERIAL LAYERS), AQUIFER TOO DEEP, CONTAMINANT MIGRATION, SULFATES INCREASE, ORGANIC CHEMICALS INCREASE (ORGANIC CONTAMINANTS POPS), NUTRIENT ISSUES (MAINLY NITROGEN), ORGANIC MATTER, CLOGGING (CHEMICAL AND BIOLOGICAL)	(SHI ET AL., 2016)
IMPACT OF MANAGED AQUIFER RECHARGE ON THE CHEMICAL AND ISOTOPIC COMPOSITION OF A KARST AQUIFER,	DEEP WELLS	JORDAN, 40 KM NEAR AMMAN	NA	PROBLEMS – LIMITED KNOWLEDGE ABOUT HYDRAULIC AND GEOLOGIC CHARACTERISTICS OF THE ZONE, WATER SCARCITY (CLIMATE), KARSTIC AQUIFER ISSUES (DISSOLUTION), HYDROLOGICAL IMBALANCE, SALINITY ISSUES (BUT NOT DUE TO SODICITY), SULFATE	(XANKE ET AL., 2015)

CASE	RECHARGE TYPE	PLACE & TIME	DURATION OF THE PROJECT	MAIN PROBLEMS	REFERENCE
WALA RESERVOIR, JORDAN				ISSUES, NUTRIENTS, CHLORIDE, CLOGGING (PHYSICAL), SUSPENDED SOLIDS, LOW INFILTRATION RATE	
NATURAL ATTENUATION OF CHLOROBENZENE IN A DEEP COFINED AQUIFER DURING ARTIficIAL RECHARGE PROCESS	NA	SOUTH-WEST CHINA	NA	PROBLEMS – ORGANIC CHEMICALS (POPS), SUSPENDED SOLIDS, CHLORIDE, LAND USE PROBLEMS (USES OF LAND FOR AGRICULTURE, INDUSTRY AND RESIDENTIAL HAVE DETERIORATED WATER QUALITY), WATER USES (INDUSTRY, URBAN AND AGRICULTURE),	(HE ET AL., 2016)
ARTFICIAL RECHARGE OF THE PHREATIC AQUIFER IN THE UPPER FRIULI PLAIN, ITALY, BY A LARGE INFILTRATION BASIN	INFILTRATION BASIN	ITALY	NA	PROBLEMS – LOW PERMEABILITY, NUTRIENT ISSUES (NITROGEN MAINLY), SULFATES, OVERLAPPING OF DIFFEREND GEOLOGICAL LAYERS (WITH CLAY), GEOLOGICAL/HYDRAULIC INFORMATION, HYDRAULIC IMBALANCE (INPUT OUTPUT OF THE RECHARGE IS NEGATIVE) NOT PROBLEM – LOW SALINITY	(TEATINI ET AL., 2015)
WATER QUALITY OF THE LITTLE ARKANSAS RIVER AND EQUUS BEDS AQUIFER BEFORE AND CONCURRENT WITH LARGE-SCALE ARTIFICIAL RECHARGE, SOUTH-CENTRAL KANSAS, 1995–2012	DEEP WELLS	USA (KANSAS) 1995	6 YEARS	PROBLEMS – CHLORIDE, NUTRIENT ISSUES (MAINLY NITROGEN), TRACE ELEMENTS PROBLEMS (METALS MAINLY), NOT ENOUGH WATER RECHARGED (WATER INPUT IS TOO LOW COMPARED TO THE EXTRACTION AND THE TOTAL VOLUME OF THE AQUIFER), ORGANIC CHEMICALS (POPS), MICROBIOLOFGICAL ISSUES (FECAL BACTERIA)	(GALLEGOS AND VARELA, 2015)
ARTIFICAL RECHARGE IN LAS VEGAS VALLEY, CLARK COUNTY NEVADA	INJEECTION WELLS / DEEP WELLS	USA (LAS VEGAS)	NA	PROBLEMS – HIGH THICKNESS AND NOT SHALLOW AQUIFER, SULFATE CONTENT, SODIUM CONTENT, CHLORIDE CONTENT, WATER MIXTURE, LOW WELL RECHARGE YIELD (PROBABLY DUE TO CLOGGING BUT UNKNOWN TYPE), ECONOMIC CONSTRAINTS (OPERATONAL)	(KATZER AND BROTHERS, 1989)
WATER QUALITY CHANGES RELATED TO THE DEVELOPMENT OF ANAEROBIC CONDITIONS DURING ARTIFICIAL RECHARGE	INFILTRATION BASINS	USA (TEXAS)	NA	PROBLEMS – LOW INFILTRATION RATE, SODICITY/SALINITY ISSUES, HIGH SULFATE, HIGH CHLORIDE, VEGETATION/ALGAE GROWTH, GENERATION OF METABOLITES (H_2S), LOW PH, CLOGGING (BIOLOGICAL) NOT PROBLEM – LOW SUSPENDED SOLIDS CONTENT	(WOOD AND BASSETT, 1975)

CASE	RECHARGE TYPE	PLACE & TIME	DURATION OF THE PROJECT	MAIN PROBLEMS	REFERENCE
A THIRTY YEAR ARTIFICIAL RECHARGE EXPERIMENT IN COASTAL AQUIFER IN AN ARID ZONE: THE TEBOULBA AQUIFER SYSTEM (TUNISIAN SAHEL)	DEEP WELLS / INJECTION WELLS	TUNISIA (SAHEL) 1972 - 2002	30 YEARS	PROBLEMS – WATER SCARCITY (DUE TO CLIMA AND PRECIPITATION), LOW QUANTITY OF WATER RESOURCES AVAILABLE FOR RECHARGE, HIGH SALINITY/SODICITY, LOW INFILTRATION RATE, LOW POROSITY, REGIONAL HYDROGEOLOGY PROBLEMS (NEGATIVE INPUT/OUTPUT RATIO) NOT PROBLEM – CHEAPER WATER PRICES, COMPARED TO OTHER TECHNOLOGIES THE PRICES AND COSTS (DESIGN/CONSTRUCTION AND OPERATION) ARE BETTER IN AQUIFER ARTIFICIAL RECHARGE	(BOURI AND DHIA, 2010)
ESTIMATING GROUNDWATER RECHARGE INDUCED BY ENGINEERING SYSTEMS IN A SEMIARID AREA (SOUTHEASTERN SPAIN)	INFILTRATION BASINS (VIA CHECK DAMS AND GRAVEL PITS)	SPAIN (ALMERIA)	NA	PROBLEMS – HIGH SLOPE, WATER SCARCITY (CLIMATE), CLOGGING (PHYSICAL) NOT PROBLEM – GOOD INFILTRATION RATE	(MARTÍN-ROSALES ET AL., 2007)
QUANTITATIVE PCR MONITORING OF ANTIBIOTIC RESISTANCE GENES AND BACTERIAL PATHOGENS IN THREE EUROPEAN ARTIFICIAL GROUNDWATER RECHARGE SYSTEMS	RIVER INFILTRATION	SPAIN (SABADELL)	1 YEAR	PROBLEMS – MICROBIOLOGICAL ISSUES, LEGAL CONSTRAINTS (DOESN'T COMPLY WITH DRINKING STANDARDS)	(BÖCKELMANN ET AL., 2009)
QUANTITATIVE PCR MONITORING OF ANTIBIOTIC RESISTANCE GENES AND BACTERIAL PATHOGENS IN THREE EUROPEAN ARTIFICIAL GROUNDWATER RECHARGE SYSTEMS	DEEP WELLS	ITALY (NARDÒ)	1 YEAR	PROBLEMS – LOW PH (POSSIBLY METAL DISSOLUTION AND MOBILISATION), WATER MIXTURE, MICROBIOLOGICAL ISSUES, WATER SCARCITY (CLIMATE), LEGAL CONSTRAINTS (DOESN'T COMPLY WITH DRINKING STANDARDS)	(BÖCKELMANN ET AL., 2009)

CASE	RECHARGE TYPE	PLACE & TIME	DURATION OF THE PROJECT	MAIN PROBLEMS	REFERENCE
QUANTITATIVE PCR MONITORING OF ANTIBIOTIC RESISTANCE GENES AND BACTERIAL PATHOGENS IN THREE EUROPEAN ARTIFICIAL GROUNDWATER RECHARGE SYSTEMS	INFILTTRATION BASINS	BELGIUM /TORREELE)	1 YEAR	PROBLEMS – WATER MIXTURE, MICROBIOLOGICAL ISSUES, DESIGN AND CONSTRUCTION COSTS, OPERATIONAL COSTS (REVERSE OSMISIS AND ULTRAFILTRATION TREATMENTS),	(BÖCKELMANN ET AL., 2009)
MODELING SEASONAL REDOX DYNAMICS AND THE CORRESPONDING FATE OF THE PHARMACEUTICAL RESIDUE PHENAZONE DURING ARTIFICIAL RECHARGE OF GROUNDWATER	DEEP WELLS	GERMANY (BERLIN)	NA	PROBLEMS – CLOGGING (UNKNOWN TYPE), LOW INFILTRATION RATE (PERIODICALLY CHANGING THIS RATE DUE TO CLOGGING ISSUES), NUTRIENTS, LOW NATURAL ATENUATION	(GRESKOWIAK ET AL., 2006)
INTEGRATED WATER MANAGEMENT FOR THE 21ST CENTURY: PROBLEMS AND SOLUTIONS	NA	NA	NA	PROBLEMS – LEGAL (OWNERSHIP,REUSE), CONTAMINATION (EXTERNAL POLUTANTS AND WASTE WATER RECHARGED POLLUTANTS), SALINITY, WATER SHORTAGE DUE TO CLIMATE CHANGE, FLOODING DUE TO CLIMATE CHANGE, NOT ENOUGH WATER EXTRACTED FROM MAR.	(BOUWER, 2002B)
GROUNDWATER RECHARGE WITH RECLAIMED MUNICIPAL WASTEWATER: HEALTH AND REGULATORY CONSIDERATIONS TAKASHI	SURFACE SPREADING AND INJECTION WELLS	NA	NA	PROBLEMS – LEGAL (HEALTH LAWS), CONTAMINATION (EXTERNAL, TRACE CONTAMINANTS, ETC.), LACK OF KNOWLEDGE ABOUT THE RISKS AND PROBLEMS,	(ASANO AND COTRUVO, 2004)
FUTURE MANAGEMENT OF AQUIFER RECHARGE	ALL	NA	NA	PROBLEMS – WATERLOGGING, DAMAGE TO STRUCTURES, FLOODING, SOIL SALINISATION, LEGAL ISSUES, WATER QUALITY, LACK OF KNOWLEDGE	(DILLON, 2005)

CASE	RECHARGE TYPE	PLACE & TIME	DURATION OF THE PROJECT	MAIN PROBLEMS	REFERENCE
MANAGED AQUIFER RECHARGE: AN ASSESSMENT OF ITS ROLE AND EFFECTIVENESS IN WATERSHED MANAGEMENT	INFILTRATION BASIN AND CHECK DAMS	KOLWAN VALLEY 1998	NA	PROBLEMS – WATER SCARCITY (TO INFILTRATE), LACK OF INFORMATION, LACK OF WORKFORCE, MAINTENANCE COSTS, LEGAL ISSUES, OWNERSHIP ISSUES, COST-BENEFIT SHRING ISSUES, TENSIONS BETWEEN GOVERNMENT/AGENCIES/PEOPLE, INCREASED WATER ABSTRACTION, CLIMATE CHANGE ISSUES, CLOGGING.	(GALE ET AL., 2006)
MANAGED AQUIFER RECHARGE: AN ASSESSMENT OF ITS ROLE AND EFFECTIVENESS IN WATERSHED MANAGEMENT	CHECK DAM AND PERCOLATION TANK	SATLASANA (MUMANVAS, BHANAVAS 1, BBHANAVAS 2 AND SAMRAPUR) 2001-2003	NA	PROBLEMS – INVESTEMENT COSTS ISSUES, LAND USE (19,5 KM2), CLOGGING, LOW WATER RETENTION, HIGH FLUORIDE, HIGH NA, HIGH NO3-,	(GALE ET AL., 2006)
MANAGED AQUIFER RECHARGE: AN ASSESSMENT OF ITS ROLE AND EFFECTIVENESS IN WATERSHED MANAGEMENT	INFILTRATION BASIN AND CHECK DAM	COIMBATORE (KARNAMPETTAI, KODAGIPALAYA1 AND KODANGIPALAYAM 2)	NA	PROBLEMS – LAND USE, SOCIAL ACCEPTANCE, HIGH COSTS, LEGAL ISSUES, OWNERSHIP ISSUES, LACK OF MAINTENANCE (DUE TO COSTS, LACK OF KNOWLEDGE AND UNWILLINGNESS), LOW INFILTRATION RATES (MAINLY DUE TO CLOGGING), HIGH CONCENTRATIONS OF BA, FE AND NO3-	(GALE ET AL., 2006)
ORGANIC MICROPOLLUTANT REMOVAL FROM WASTEWATER EFFLUENT-IMPACTED DRINKING WATER SOURCES DURING BANK FILTRATION AND ARTIFICIAL RECHARGE	BANK FILTRATION AND INFILTRATION BASIN	GERMANY 2002	3 YEARS	PROBLEMS – VERY HIGH RETENTION TIME FOR BANK FILTRATION, VERY SHORT RETENTION TIME FOR INFILTRATION BASIN, BOTH HAD PROBLEMS WITH WATER QUALITY (MICROPOLLUTANTS, MOSTLY PHARMACEUTICAL PRODUCTS).	(MAENG ET AL., 2010)

CASE	RECHARGE TYPE	PLACE & TIME	DURATION OF THE PROJECT	MAIN PROBLEMS	REFERENCE
BIOGEOCHEMICAL PROCESSES DURING THE INFILTRATION OF RIVER WATER INTO AN ALLUVIAL AQUIFER	RIVERBANK FILTRATION	FRANCE	NA	PROBLEMS – SEDIMENTS WHERE WATER INFILTRATES ARE CONTAMINATED WITH ZINC AND CADMIUM	(SITE, 1993)
USE OF STATIC QUANTITATIVE MICROBIAL RISK ASSESSMENT TO DETERMINE PATHOGEN RISKS IN AN UNCONFINED CARBONATE AQUIFER USED FOR MANAGED AQUIFER RECHARGE SIMON	INJECTION WELLS	AUSTRALIA	NA	PROBLEMS – CHEMICAL CLOGGING	(TOZE ET AL., 2010)
STUDY OF THE FEASIBILITY OF AN AQUIFER STORAGE AND RECOVERY SYSTEM IN A DEEP AQUIFER IN BELGIUM	INJECTION WELLS	BELGIUM	NA	PROBLEMS – QUALITY ISSUES DUE TO WATER MIXING, LOW AMOUNT OF RECOVERED WATER, QUALITY ISSUES (PHOSPHATE, WATER COLOUR, DOC), CLOGGING (PHYSICAL AND BIOLOGICAL).	(VANDENBOHEDE ET AL., 2008)
EFFECTIVENESS OF RIVERBANK FILTRATION FOR REMOVAL OF NITROGEN FROM HEAVILY POLLUTED RIVERS: A CASE STUDY OF KUIHE RIVER, XUZHOU, JIANGSU, CHINA	RIVERBANK FILTRATION	CHINA	NA	PROBLEMS – QUALITY ISSUES (HIGH NITROGEN CONCENTRATIONS), LOW DEGRADATION OF POLLUTANTS	(WU ET AL., 2007)

*MONITORING, DATA COLLECTION AND ZONE STUDY ARE ASPECTS THAT SHOULD BE TAKEN INTO ACCOUNT BECAUSE THEY CAN LEAD TO FAILURE OF THE MAR FACILITY IF THEY ARE NOT DONE CORRECTLY (MISSINFORMATION OF THE MEASURES, UNACCEPTABLE COSTS OR BAD SPATIAL DISTRIBUTION)

*CORROSION OF METAL COMPONENTS IN THE PIPES AND MACHINES IS A COMMON PROBLEM.

*INSUFICIENT EVIDENCE FOR RISK QUANTIFICATION FOR SOME ISSUES (LIKE INORGANIC CHEMICALS)

*THERE'S USUALLY THE NEED OF WWTP AND DESSALATION PLANTS TO TREAT THE WATER PRIOR TO INJECTION (MOST CASES)

*USUALLY THERE'S A LACK OF REGULATORY PRECEDENT

*USUALLY ARTIFICIAL RECHARGE IMPLIES WATER PUMPING (FOR AGRICULTURAL, INDUSTRIAL OR URBAN USES) SO MAYBE THERE'S AN IMBALANCE BETWEEN THE WATER ENTERING THE SYSTEM AND THE WATER BEING PUMPED OUT OF IT

*THERE SHOULD BE INCLUDED A FAILURE DUE TO LATERAL INFILTRATION INSTEAD OF VERTICAL INFILTRATION

*GENERATION OF METABOLITES IS AN ISSUE THAT USUALLY HAPPENS WHERE THERE ARE MICROBIOLOGICAL PROBLEMS

*STORM QUALITY MONITORING IS IMPORTANT IN ORDER TO IDENTIFY AND CONTROL WATER INPUTS TO THE SYSTEM (KNOWING THEIR QUALITY AND QUANTITY)

*SOMETIMES THE PROBLEM IS NOT THE INFILTRATION RATE BUT THE POROSITY OR CONDUCTIVITY

S2. LITERARURE REVIEW OF MANAGED AQUIFER RECHARGE FAILURES

LEG	Legal constraints - Changes in the legislation or failures to comply with its requirements (especially for health or environmental legislation).
TER	Territorial constraints
EU	European
NAT	National
REG	Regional/Local
SC	Scope of legislation – Depending on the legislation type, its restrictions and risk probabilities can be significantly different.
HTH	Health legislation
OTH	Others – Mainly environmentally related legislation that can pose some kind of restrictions to the operation of the Mar facility.
ECO	Economic constraints
MAC	Macroeconomic constraints – Restrictions related to global effects on economy like crisis, changes in currency value, increase of the petroleum price, etc. That may cause a reduction on the interest in recharging water or a reduction on the quantity recharged.
MIC	Microeconomic constraints
NEWR	Not enough water to recharge due to other economical uses
IND	Industrial use
AGR	Agricultural use
DOM	Domestic use
COST	Cost restriction
LWP	Low price of water – MAR has fixed costs and the water that produces has a fixed price, however other water sources can have a variable price that may be cheaper than the water obtained by MAR sources and therefore, the incentive for developing MAR is lowered.
HCST	High installation cost
MAINT	High maintenance cost/maintenance requirements
FUND	Lack of private/public funding
SO	Social unacceptance – Neighbors and other citizens may dislike MAR due to their own opinions according to safety, health, noise, etc.
HTHR	Health risk perception
HCOST	High cost perception
BRH	Behavioral requirements – MAR as any technical facility has safety procedures and a code of conduct for the workers and people related to the facility operation. Thus implying that people may be unwilling to accept a MAR facility because they fear a facility that needs safety requirements like these.
CHILD	Children surveillance
FAIR	Fair distribution of treated water

EFECT	Perception of effectiveness
GOV	Governance
CORD	Lack of coordination
NTK	Non-technical knowledge
SD	Structural Damages
FL	Flooding
NH	Natural hazards (e.g. earthquake)
TA	Terrorism activities/Vandalism
CV	Civil work failures
SLP	Slope stability – Mostly for surface infiltration, it implies that the water recharge or accumulation in storage ponds may cause instabilities in the slopes and possibly causing landfalls or wall breakages.
PB	Pipe breakage
OTH	Others
AD	Aquifer dissolution (e.g. in karstic aquifer)
QUAT	Not enough water recharged
LWIP	Low quality water
BIO	Sanitary/biological restrictions (e.g. due the pathogens)
PHY	Physical restrictions
TP	Turbidity/particles
CHE	Chemical restrictions
MET	Metals (e.g. arsenic, manganese)
SL	Salinity and sodicity
NUT	Nutrients (nitrogen, phosphorous)
OC	Organic chemicals (pollutants, EOCs)
RN	Radionuclides
WS	Water scarcity
CLIM	Climate
DRO	Droughts
WWTP	Waste water treatment plant failure
LAND	Desalination plant failure
RIV	River regulation
CLOG	Clogging

PCL Physical clogging

FDP Failure deposition pond (particles from diverted water) – The particles may not be sedimented efficiently and still be present in the recharged water, diminishing and difficulting the entrance of water during recharge operations.

PPF Pipe filter fails

RT Residence time – Not enough residence time may cause an inefficient reduction and degradation of contaminants and pathogens.

SFP Source fine particles (generation inside MAR facility)

TD Transport sedimentation (erosion or deposition from recharge pond)

DP Deposition

ER Erosion

BCL Bioclogging

CCL Chemical clogging

EV Evaporation (excess)

WMX Water mixtures – The combination of the aquifer natural water and the injected water may cause precipitation of minerals and therefore chemical clogging, reducing the amount of water recharged into the aquifer.

MIC Microbial population catalysis – Microbial population may cause changes in the water chemistry which in turn can imply precipitation of minerals or other byproducts (microbial biofilms) which can reduce recharged water.

COM Compaction

GAS Generation of gas (e.g. bubble formation)

PHM Physical Motives

BAC Bacterial processes

ID Inappropriate design

QUAL Unacceptable quality of water at sensitive location

AN Inefficient natural attenuation

OM Organic matter

EOC Emerging organic compounds

UN Nutrients

MET Generation of metabolites – The chemicals injected or already present in the aquifer may be degraded and then transformed into another compounds which may be equally or more dangerous than the previous ones, therefore affecting the quality of the water.

NC Nitrogen cycle (NO_2^-, N_2O…)

EOC Emerging organic compounds

H_2S Other nutrient cycles (H_2S)

MOB Mobilization

MET Metals

ST Specific targets – A MAR project can be done for many reasons but there is always one or a couple of them that are the main ones for the project. Those reasons may have specific objectives that need to be achieved in order to have a successful MAR project.

SWB Seawater barriers

PROT Protected water body

WL Water levels

RIV River

SPR Spring

WET Wetland

S3. RISKMAR APP MANUAL

The programming language of the MAR-RISKAPP was Visual Basic. Which is based on the usage of macros, which are usually short programing code lines that are used to give some kind of orders to the program in order to do some specific calculations or to set automatically some kind of properties for the working environment (among other kind of possibilities) and objects.

The result was the MAR-RISKAPP tool which allows the user to define four probability categories (high risk, medium risk, low risk and no risk) of failure for each type MAR event and therefore calculate the risk of a general MAR failure (representing the different probabilities within a fault tree).

The MAR-RISKAPP was structured in four main steps: 1) HOME, 2) INPUT, 3) RESULTS and 4) GRAPHICAL RESULTS.

The application starts with the HOME step. This first stage shows the name of the tool, the creators and the main institutions involved in it, with a clear indication that the tool was developed within the framework of project MARSOL. From this starting point, there are two possible ways to proceed: 1) HELP (which sends the user to a general explanation of the tool and its operational set can be found), and 2) START (which sends the user to the second step of the tool – INPUT).

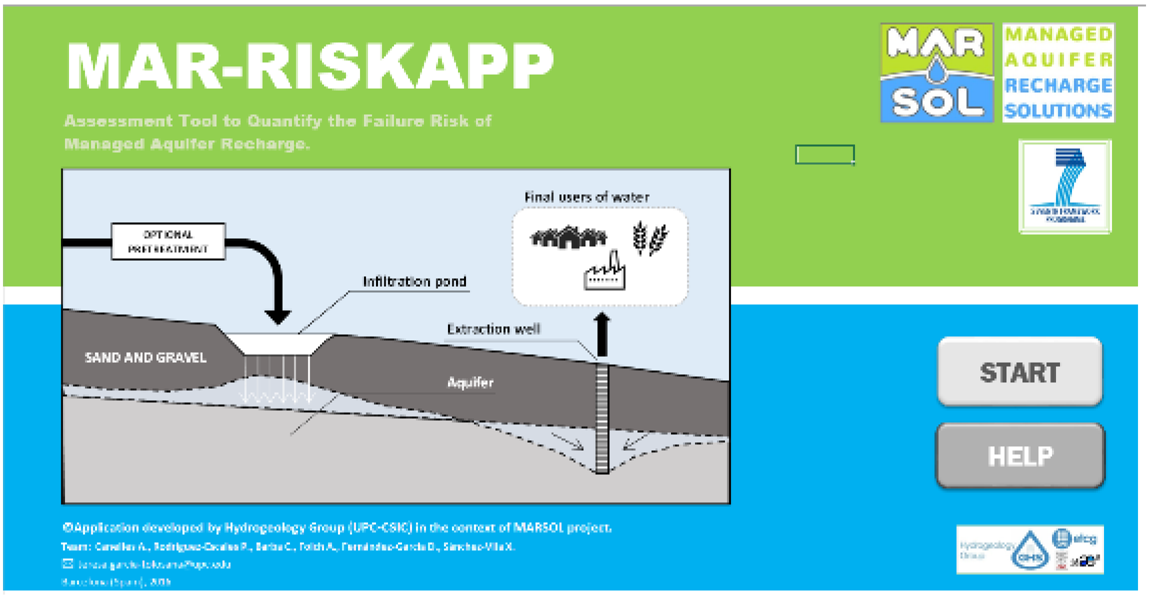


Figure S3.1. Home layout visualization.

The second step of the tool is INPUT. At this point, the user has to choose the risk category of the different events for both non-technical and technical issues (the Input sheet can be seen in Figure S3.2). This step implies that data has to be filled in four different sheets: 1) NON-TECHNICAL CONSTRAINTS - DESIGN AND CONSTRUCTION (Figure S3.3), 2) TECHNICAL CONSTRAINTS - DESIGN AND CONSTRUCTION (Figure S3.4), 3) NON-TECHNICAL CONSTRAINTS – OPERATION (Figure S3.5) and 4) TECHNICAL CONSTRAINTS – OPERATION (Figure S3.6). Where the user has to answer for all the events by writing an “X” on the risk category that they think it is the most adequate.

Only one “X” has to be written at each line, as the person filling the sheet must select one of the following four categories of risk: no risk, high risk, medium risk, or low risk. In the Input worksheet, there is a button of instructions; when this button is clicked, a pop-up text box is shown (which indicates the order that the four input sheets should be filled and some explanation about their meaning). In addition, each input sheet has its own instruction button, which explains the user by using text and images, how to fill the surveys from each input worksheet. Finally, when all the input sheets have been filled, the user can run the Results button in order to go the RESULTS sheet (or if the user need help, the Help button can bring him/her to the Help sheet, or if the user wants to go back to the HOME sheet, he/she can press the BACK TO HOME button).

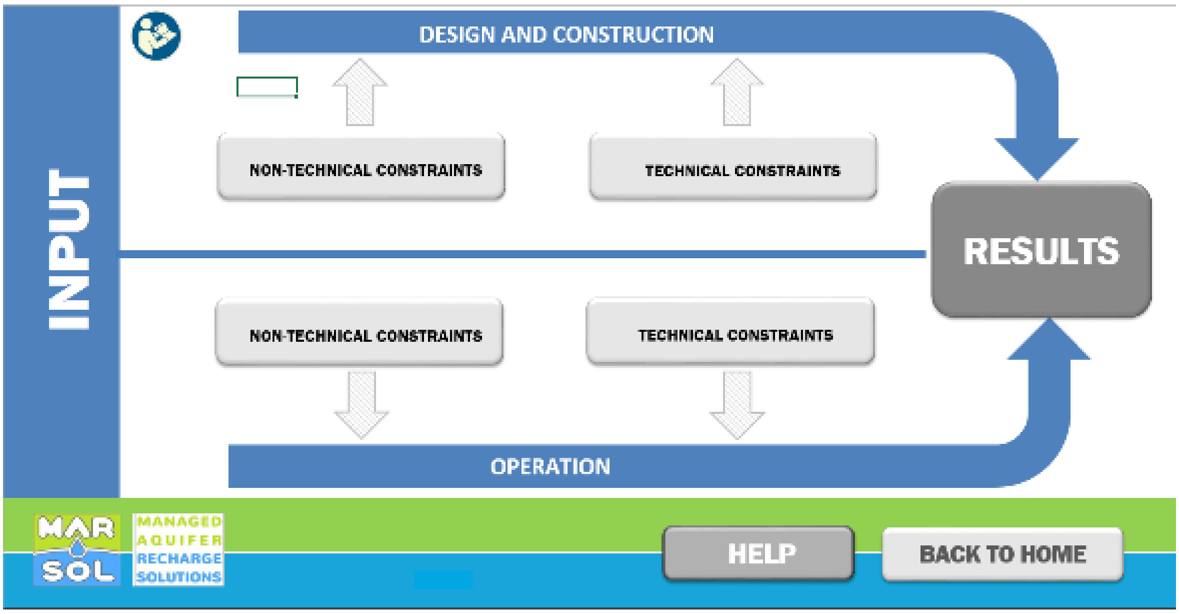
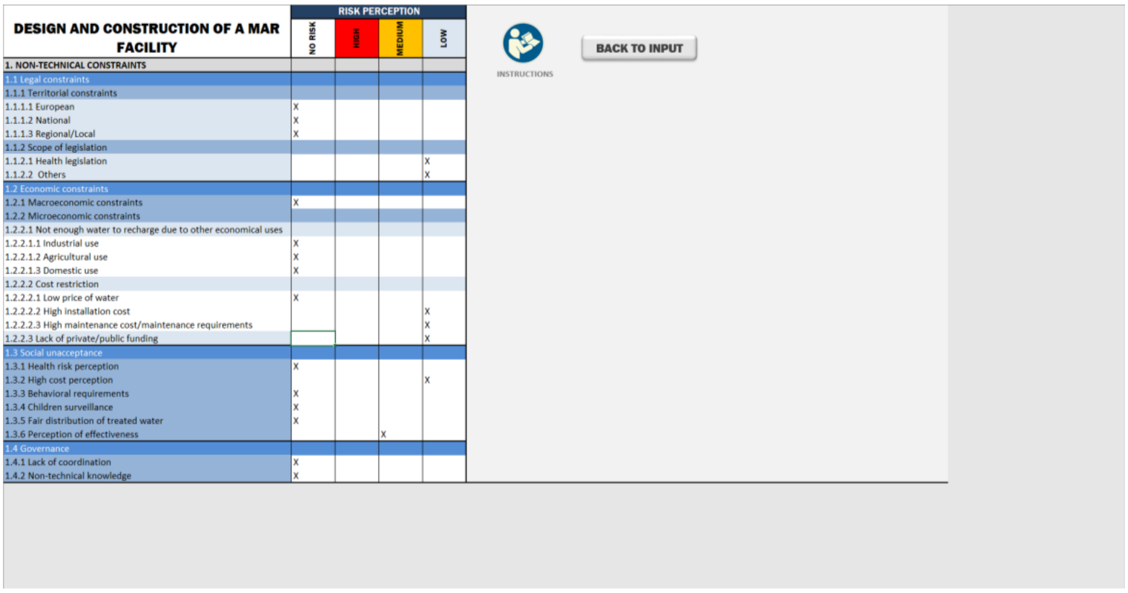
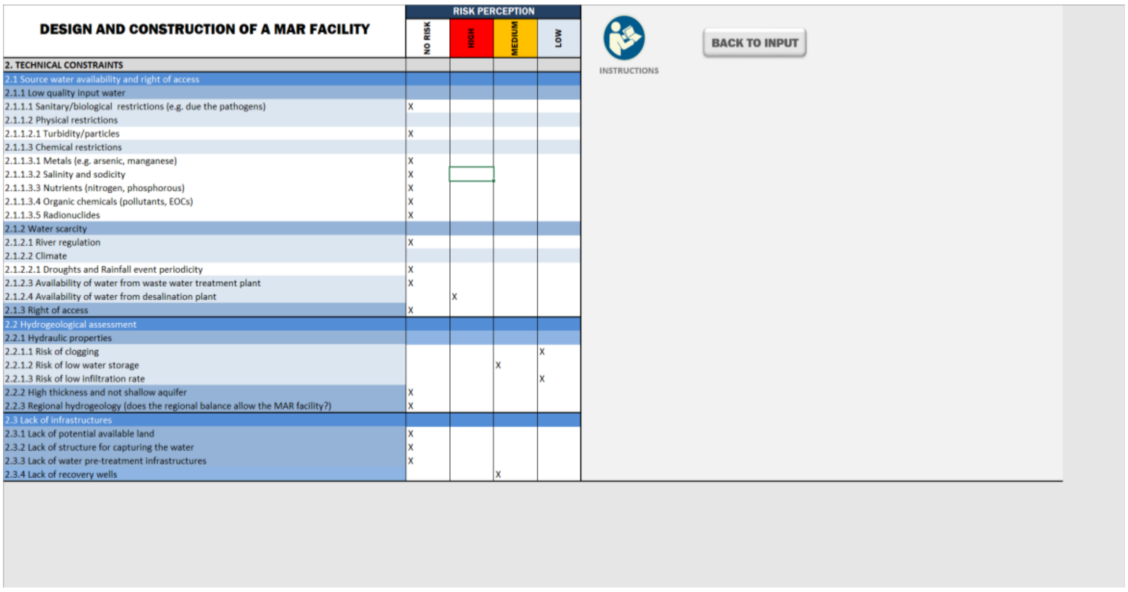


Figure S3.2. Input layout visualization



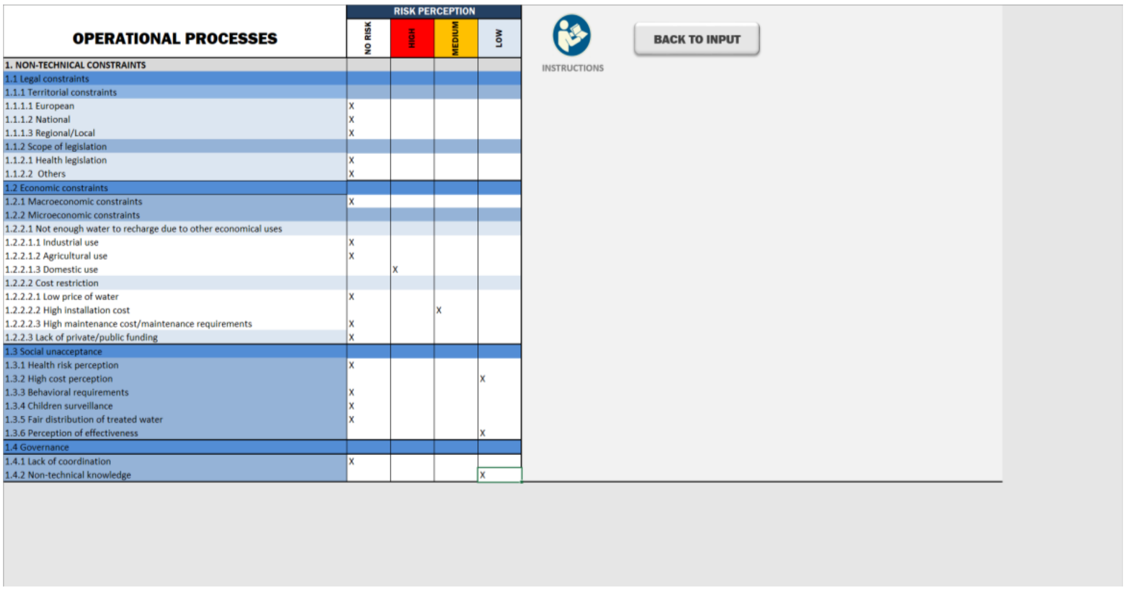
DESIGN AND CONSTRUCTION OF A MAR FACILITY	RISK PERCEPTION			
	NO RISK	HIGH	MEDIUM	LOW
1. NON-TECHNICAL CONSTRAINTS				
1.1 Legal constraints				
1.1.1 Territorial constraints				
1.1.1.1 European	X			
1.1.1.2 National	X			
1.1.1.3 Regional/Local	X			
1.1.2 Scope of legislation				
1.1.2.1 Health legislation				X
1.1.2.2 Others				X
1.2 Economic constraints				
1.2.1 Macroeconomic constraints	X			
1.2.2 Microeconomic constraints				
1.2.2.1 Not enough water to recharge due to other economical uses				
1.2.2.1.1 Industrial use	X			
1.2.2.1.2 Agricultural use	X			
1.2.2.1.3 Domestic use	X			
1.2.2.2 Cost restriction				
1.2.2.2.1 Low price of water	X			
1.2.2.2.2 High installation cost				X
1.2.2.2.3 High maintenance cost/maintenance requirements				X
1.2.2.3 Lack of private/public funding				X
1.3 Social unacceptance				
1.3.1 Health risk perception	X			
1.3.2 High cost perception				X
1.3.3 Behavioral requirements	X			
1.3.4 Children surveillance	X			
1.3.5 Fair distribution of treated water	X			
1.3.6 Perception of effectiveness			X	
1.4 Governance				
1.4.1 Lack of coordination	X			
1.4.2 Non-technical knowledge	X			

Figure S3.3. Non-technical constraints – Design and construction, sheet visualization.



DESIGN AND CONSTRUCTION OF A MAR FACILITY	RISK PERCEPTION			
	NO RISK	HIGH	MEDIUM	LOW
2. TECHNICAL CONSTRAINTS				
2.1 Source water availability and right of access				
2.1.1 Low quality input water				
2.1.1.1 Sanitary/biological restrictions (e.g. due the pathogens)	X			
2.1.1.2 Physical restrictions				
2.1.1.2.1 Turbidity/particles	X			
2.1.1.3 Chemical restrictions				
2.1.1.3.1 Metals (e.g. arsenic, manganese)	X			
2.1.1.3.2 Salinity and sodicity	X			
2.1.1.3.3 Nutrients (nitrogen, phosphorous)	X			
2.1.1.3.4 Organic chemicals (pollutants, EOCs)	X			
2.1.1.3.5 Radionuclides	X			
2.1.2 Water scarcity				
2.1.2.1 River regulation	X			
2.1.2.2 Climate				
2.1.2.2.1 Droughts and Rainfall event periodicity	X			
2.1.2.3 Availability of water from waste water treatment plant	X			
2.1.2.4 Availability of water from desalination plant		X		
2.1.3 Right of access	X			
2.2 Hydrogeological assessment				
2.2.1 Hydraulic properties				
2.2.1.1 Risk of clogging				X
2.2.1.2 Risk of low water storage			X	
2.2.1.3 Risk of low infiltration rate				X
2.2.2 High thickness and not shallow aquifer	X			
2.2.3 Regional hydrogeology (does the regional balance allow the MAR facility?)	X			
2.3 Lack of infrastructures				
2.3.1 Lack of potential available land	X			
2.3.2 Lack of structure for capturing the water	X			
2.3.3 Lack of water pre-treatment infrastructures	X			
2.3.4 Lack of recovery wells			X	

Figure S3.4. Technical constraints – Design and construction, sheet visualization.



OPERATIONAL PROCESSES	RISK PERCEPTION			
	NO RISK	HIGH	MEDIUM	LOW
1. NON-TECHNICAL CONSTRAINTS				
1.1 Legal constraints				
1.1.1 Territorial constraints				
1.1.1.1 European	X			
1.1.1.2 National	X			
1.1.1.3 Regional/Local	X			
1.1.2 Scope of legislation				
1.1.2.1 Health legislation	X			
1.1.2.2 Others	X			
1.2 Economic constraints				
1.2.1 Macroeconomic constraints	X			
1.2.2 Microeconomic constraints				
1.2.2.1 Not enough water to recharge due to other economical uses				
1.2.2.1.1 Industrial use	X			
1.2.2.1.2 Agricultural use	X			
1.2.2.1.3 Domestic use		X		
1.2.2.2 Cost restriction				
1.2.2.2.1 Low price of water	X			
1.2.2.2.2 High installation cost			X	
1.2.2.2.3 High maintenance cost/maintenance requirements	X			
1.2.2.3 Lack of private/public funding	X			
1.3 Social unacceptance				
1.3.1 Health risk perception	X			
1.3.2 High cost perception				X
1.3.3 Behavioral requirements	X			
1.3.4 Children surveillance	X			
1.3.5 Fair distribution of treated water	X			
1.3.6 Perception of effectiveness				X
1.4 Governance				
1.4.1 Lack of coordination	X			
1.4.2 Non-technical knowledge				X

Figure S3.5. Non-technical constraints – Operation, sheet visualization.

OPERATIONAL PROCESSES	RISK PERCEPTION			
	NO RISK	HIGH	MEDIUM	LOW
2. TECHNICAL CONSTRAINTS				
2.1 Structural Damages				
2.1.1 Flooding				X
2.1.2 Natural hazards (e.g. earthquake)	X			
2.1.3 Terrorism activities/Vandalism			X	
2.1.4 Civil work failures				
2.1.4.1 Slope stability				X
2.1.4.2 Pipe breakage				X
2.1.4.3 Others				X
2.1.5 Aquifer dissolution (e.g. in karstic aquifer)				X
2.2 Not enough water recharged				
2.2.1 Low quality water				
2.2.1.1 Sanitary/biological restrictions (e.g. due the pathogens)	X			
2.2.1.2 Physical restrictions				
2.2.1.2.1 Turbidity/particles	X			
2.2.1.3 Chemical restrictions				
2.2.1.3.1 Metals (e.g. arsenic, manganese)	X			
2.2.1.3.2 Salinity and sodicity	X			
2.2.1.3.3 Nutrients (nitrogen, phosphorous)	X			
2.2.1.3.4 Organic chemicals (pollutants, EOCs)	X			
2.2.1.3.5 Radionuclides	X			
2.2.2 Water scarcity				
2.2.2.1 Climate				
2.2.2.1.1 Droughts and Rainfall event periodicity	X			
2.2.2.2 Waste water treatment plant failure	X			
2.2.2.3 Desalination plant failure	X			
2.2.2.4 River regulation	X			
2.2.3 Clogging				
2.2.3.1 Physical clogging				
2.2.3.1.1 Failure deposition pond (particles from diverted water)				
2.2.3.1.1.1 Pipe filter fails	X			
2.2.3.1.1.2 Residence time	X			
2.2.3.1.2 Source fine particles (generation inside MAR facility)	X			
2.2.3.1.3 Transport sedimentation (erosion or deposition from recharge pond)				
2.2.3.1.1.2 Residence time	X			
2.2.3.1.2 Source fine particles (generation inside MAR facility)	X			
2.2.3.1.3 Transport sedimentation (erosion or deposition from recharge pond)				
2.2.3.1.3.1 Deposition	X			
2.2.3.1.3.2 Erosion	X			
2.2.3.2 Bioclogging	X			
2.2.3.3 Chemical clogging				
2.2.3.3.1 Evaporation (excess)	X			
2.2.3.3.2 Water mixtures	X			
2.2.3.3.3 Microbial population catalysis	X			
2.2.3.4 Compaction				X
2.2.3.5Generation of gas (e.g. bubble formation)				
2.2.3.5.1 Physical Motives	X			
2.2.3.5.2 Bacterial processes	X			
2.2.3.5.3 Inappropriate design	X			
2.3 Unacceptable quality of water at sensitive location				
2.3.1 Inefficient natural attenuation				
2.3.1.1 Organic matter	X			
2.3.1.2 Emerging organic compounds	X			
2.3.1.3 Nutrients	X			
2.3.2 Generation of metabolites				
2.3.2.1 Nitrogen cycle (NO2-, N2O…)	X			
2.3.2.2 Emerging organic compounds				X
2.3.2.3 Other nutrient cycles (H2S)	X			
2.3.3 Mobilization				
2.3.3.1 Metals	X			
2.4 Specific targets (is it important to you?)				
2.4.1 Seawater barriers	X			
2.4.2 Protected water body	X			
2.4.3 Water levels				
2.4.3.1 River	X			
2.4.3.2 Spring	X			
2.4.3.3 Wetland	X			
2.4.3.4 Groundwater	X			

INSTRUCTIONS

BACK TO INPUT

Figure S3.6. Technical constraints – Operation, sheet visualization.

The third step is RESULTS. This part shows the user the numerical results of the risk assessment (Figure S3.8). The risk assessment is calculated within the same Results sheet by applying the values present in the A PRIORI CRITERIA sheet (Figure S3.7) which are chosen depending on the risk category selected from the INPUT step. Note that the a priori criteria are site dependent. For that, the MAR facility managerd must define each a priori criteria based on their knowledge about the site and its particular idiosyncrasies. As a default, A PRIORI CRITERIA values are provided in MAR-RISKAPP based on experience from a number of sites worldwide. The a prior values are probability numbers (ranging in the interval [0-1] that indicate the probability (from a period of 2-6 years) that the MAR facility fails due to that particular individual event.

DESIGN AND CONSTRUCTION OF A MAR FACILITY	HIGH	MEDIUM	LOW
1. NON-TECHNICAL CONSTRAINTS			
1.1 Legal constraints			
1.1.1 Territorial constraints			
1.1.1.1 European	0.5	0.3	0.1
1.1.1.2 National	0.5	0.3	0.1
1.1.1.3 Regional/Local	0.5	0.3	0.1
1.1.2 Scope of legislation			
1.1.2.1 Health legislation	0.5	0.3	0.1
1.1.2.2 Others	0.5	0.3	0.1
1.2 Economic constraints			
1.2.1 Macroeconomic constraints	0.4	0.1	0.05
1.2.2 Microeconomic constraints			
1.2.2.1 Not enough water to recharge due to other economical uses			
1.2.2.1.1 Industrial use	0.2	0.05	0.01
1.2.2.1.2 Agricultural use	0.2	0.05	0.01
1.2.2.1.3 Domestic use	0.2	0.05	0.01
1.2.2.2 Cost restriction			
1.2.2.2.1 Low price of water	0.2	0.05	0.01
1.2.2.2.2 High installation cost	0.2	0.05	0.01
1.2.2.2.3 High maintenance cost/maintenance requirements	0.2	0.05	0.01
1.2.2.3 Lack of private/public funding	0.4	0.1	0.05
1.3 Social unacceptance			
1.3.1 Health risk perception	0.2	0.05	0.01
1.3.2 High cost perception	0.2	0.05	0.01
1.3.3 Behavioral requirements	0.2	0.05	0.01
1.3.4 Children surveillance	0.2	0.05	0.01
1.3.5 Fair distribution of treated water	0.2	0.05	0.01
1.3.6 Perception of effectiveness	0.2	0.05	0.01
1.4 Governance			
1.4.1 Lack of coordination	0.4	0.1	0.05
1.4.2 Non-technical knowledge	0.4	0.1	0.05
2. TECHNICAL CONSTRAINTS			
2.1 Source water availability and right of access (if YES continue)			
2.1.1 Low quality input water (if YES continue)			
2.1.1.1 Sanitary/biological restrictions (e.g. due the pathogens)	0.3	0.1	0.05
2.1.1.2 Physical restrictions (if YES continue)			
2.1.1.2.1 Turbidity/particles	0.4	0.1	0.05
2.1.1.3 Chemical restrictions (if YES continue)			
2.1.1.3.1 Metals (e.g. arsenic, manganese)	0.1	0.01	0.0001
2.1.1.3.2 Salinity and sodicity	0.2	0.05	0.01
2.1.1.3.3 Nutrients (nitrogen, phosphorous)	0.2	0.05	0.01
2.1.1.3.4 Organic chemicals (pollutants, EOCs)	0.2	0.05	0.01
2.1.1.3.5 Radionuclides	0.01	0.00E+00	0
2.1.2 Water scarcity (if YES continue)			
2.1.2.1 River regulation	0.5	0.2	0.05
2.1.2.2 Climate (if YES continue)			
2.1.2.2.1 Droughts	0.5	0.2	0.05
2.1.2.3 Availability of water from waste water treatment plant	0.5	0.2	0.05
2.1.2.4 Availability of water from desalination plant	0.5	0.2	0.05
2.1.3 Right of access	0.5	0.2	0.05
2.2 Hydrogeological assessment (if YES continue)			
2.2.1 Hydraulic properties			
2.2.1.1 Risk of clogging	0.4	0.1	0.05
2.2.1.2 Risk of low water storage	0.4	0.1	0.05
2.2.1.3 Risk of low infiltration rate	0.4	0.1	0.05
2.2.2 High thickness and not shallow aquifer	0.4	0.1	0.05
2.2.3 Regional hydrogeology (does the regional balance allow the MAR facili	0.4	0.1	0.05
2.3 Lack of infrastructures			
2.3.1 Lack of potential available land	0.5	0.3	0.1
2.3.2 Lack of structure for capturing the water	0.1	1.00E-05	1.00E-07
2.3.3 Lack of water pre-treatment infrastructures	0.1	1.00E-05	1.00E-07
2.3.4 Lack of recovery wells	0.1	1.00E-05	1.00E-07

OPERATIONAL PROCESSES	HIGH	MEDIUM	LOW
1. NON-TECHNICAL CONSTRAINTS			
1.1 Legal constraints			
1.1.1 Territorial constraints			
1.1.1.1 European	0.25	0.15	0.05
1.1.1.2 National	0.25	0.15	0.05
1.1.1.3 Regional/Local	0.25	0.15	0.05
1.1.2 Scope of legislation			
1.1.2.1 Health legislation	0.25	0.15	0.05
1.1.2.2 Others	0.25	0.15	0.05
1.2 Economic constraints			
1.2.1 Macroeconomic constraints	0.4	0.1	0.05
1.2.2 Microeconomic constraints			
1.2.2.1 Not enough water to recharge due to other economical uses			
1.2.2.1.1 Industrial use	0.2	0.05	0.01
1.2.2.1.2 Agricultural use	0.2	0.05	0.01
1.2.2.1.3 Domestic use	0.2	0.05	0.01
1.2.2.2 Cost restriction			
1.2.2.2.1 Low price of water	0.02	0.005	0.001
1.2.2.2.2 High installation cost	0.02	0.005	0.001
1.2.2.2.3 High maintenance cost/maintenance requirements	0.2	0.05	0.01
1.2.2.3 Lack of private/public funding	0.4	0.1	0.05
1.3 Social unacceptance			
1.3.1 Health risk perception	0.3	0.1	0.05
1.3.2 High cost perception	0.3	0.1	0.05
1.3.3 Behavioral requirements	0.3	0.1	0.05
1.3.4 Children surveillance	0.3	0.1	0.05
1.3.5 Fair distribution of treated water	0.3	0.1	0.05
1.3.6 Perception of effectiveness	0.3	0.1	0.05
1.4 Governance			
1.4.1 Lack of coordination	0.4	0.1	0.05
1.4.2 Non-technical knowledge	0.4	0.1	0.05
2. TECHNICAL CONSTRAINTS			
2.1 Structural Damages (if YES continue)			
2.1.1 Flooding	0.1	0.05	0.01
2.1.2 Natural hazards (e.g. earthquake)	0.00001	0.000001	0.0000001
2.1.3 Terrorism activities/Vandalism	0.2	0.1	0.05
2.1.4 Civil work failures (if YES continue)			
2.1.4.1 Slope stability	0.05	0.025	0.01
2.1.4.2 Pipe breakage	0.2	0.1	0.05
2.1.4.3 Others	0.1	0.05	0.01
2.1.5 Aquifer dissolution (e.g. in karstic aquifer)	0.001	0.0001	0.00001
2.2 Not enough water recharged (if YES continue)			
2.2.1 Low quality water (if YES continue)			
2.2.1.1 Sanitary/biological restrictions (e.g. due the pathogens)	0.3	0.1	0.05
2.2.1.2 Physical restrictions (if YES continue)			
2.2.1.2.1 Turbidity/particles	0.4	0.1	0.05
2.2.1.3 Chemical restrictions (if YES continue)			
2.2.1.3.1 Metals (e.g. arsenic, manganese)	0.1	0.01	0.0001
2.2.1.3.2 Salinity and sodicity	0.2	0.05	0.01
2.2.1.3.3 Nutrients (nitrogen, phosphorous)	0.2	0.05	0.01
2.2.1.3.4 Organic chemicals (pollutants, EOCs)	0.2	0.05	0.01
2.2.1.3.5 Radionuclides	0.01	0.00E+00	0
2.2.2 Water scarcity (if YES continue)			
2.2.2.1 Climate (if YES continue)			
2.2.2.1.1 Droughts	0.5	0.2	0.05
2.2.2.2 Waste water treatment plant failure	0.5	0.2	0.05
2.2.2.3 Desalination plant failure	0.5	0.2	0.05
2.2.2.4 River regulation	0.5	0.2	0.05
2.2.3 Clogging (if YES continue)			
2.2.3.1 Physical clogging (if YES continue)			
2.2.3.1.1 Failure deposition pond (particles from diverted water)			
2.2.3.1.1.1 Pipe filter fails	0.4	0.1	0.05
2.2.3.1.1.2 Residence time	0.4	0.1	0.05
2.2.3.1.2 Source fine particles (generation inside MAR facility)	0.4	0.1	0.05
2.2.3.1.3 Transport sedimentation (erosion or deposition from recharge pond)			
2.2.3.1.3.1 Deposition	0.4	0.1	0.05
2.2.3.1.3.2 Erosion	0.47	0.24	0.29
2.2.3.2 Bioclogging	0.1	0.05	0.025
2.2.3.3 Chemical clogging (if YES continue)			
2.2.3.3.1 Evaporation (excess)	0.05	0.025	0.01
2.2.3.3.2 Water mixtures	0.05	0.025	0.01
2.2.3.3.3 Microbial population catalysis	0.05	0.025	0.01
2.2.3.4 Compaction	0.2	0.1	0.05
2.2.3.5Generation of gas (e.g. bubble formation) (if YES continue)			
2.2.3.5.1 Physical Motives	0.01	0.001	0.0001
2.2.3.5.2 Bacterial processes	0.1	0.05	0.025
2.2.3.5.3 Inappropriate design	0.01	0.001	0.0001
2.3 Unacceptable quality of water at sensitive location (if YES continue)			
2.3.1 Inefficient natural attenuation (if YES continue)			
2.3.1.1 Organic matter	0.1	0.05	0.01
2.3.1.2 Emerging organic compounds	0.2	0.1	0.01
2.3.1.3 Nutrients	0.15	0.1	0.05
2.3.2 Generation of metabolites (if YES continue)			
2.3.2.1 Nitrogen cycle (NO2-, N2O...)	0.15	0.1	0.05
2.3.2.2 Emerging organic compounds	0.15	0.1	0.05
2.3.2.3 Other nutrient cycles (H2S)	0.15	0.1	0.05
2.3.3 Mobilization (if YES continue)			
2.3.3.1 Metals	0.01	0.001	0.0001
2.4 Specific targets (is it important to you?)			
2.4.1 Seawater barriers	0.01	0.001	0.0001
2.4.2 Protected water body	0.01	0.001	0.0001
2.4.3 Water levels (if YES continue)			
2.4.3.1 River	0.01	0.001	0.0001
2.4.3.2 Spring	0.01	0.001	0.0001
2.4.3.3 Wetland	0.01	0.001	0.0001
2.4.3.4 Groundwater	0.01	0.001	0.0001

Figure S3.7. Expert Criteria values for the Llobregat site.

The initial prior values are presented in the DEFAULT VALUE column, and are blocked to changes by the user. Next to this column, there is the CATEGORY DEFAULT VALUES column, which indicates the risk category that the user selected in the INPUT sheets. There is also a third column called USER VALUES, that can be modified by the user in order to change the specific risk values (from the DEFAULT VALUES column) if the user has better data than the default calculations for a specific study site (but does not want to change the a priori criteria values). This third column is the one that will be used in the following calculations, so the user has to be fully aware that its modification has direct consequences on the results. The tool indicates the user if these USER VALUES have been modified or not from the default ones (this is done by filling the USER VALUES cells with red color, to indicate that both columns have the same values). Similarly, to the other steps, a HELP button can be found, and also some instructions pop-up (Figure S3.9) if the instructions button is clicked. The user can change some data from the INPUT by clicking the BACK TO INPUT button. If everything is correct, the user can go to the next step by clicking the GRAPHICAL RESULTS button.

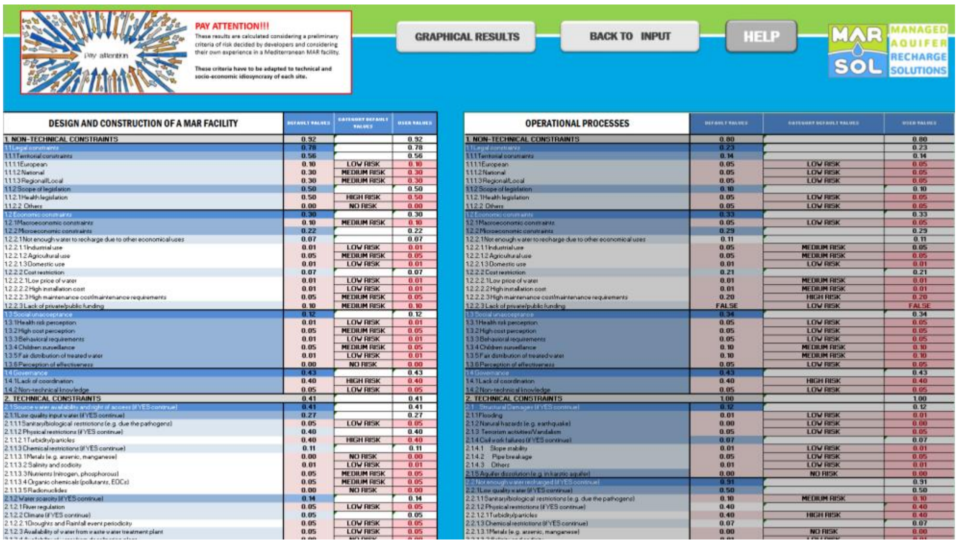


Figure S3.8. Results (upper part) sheet visualization.

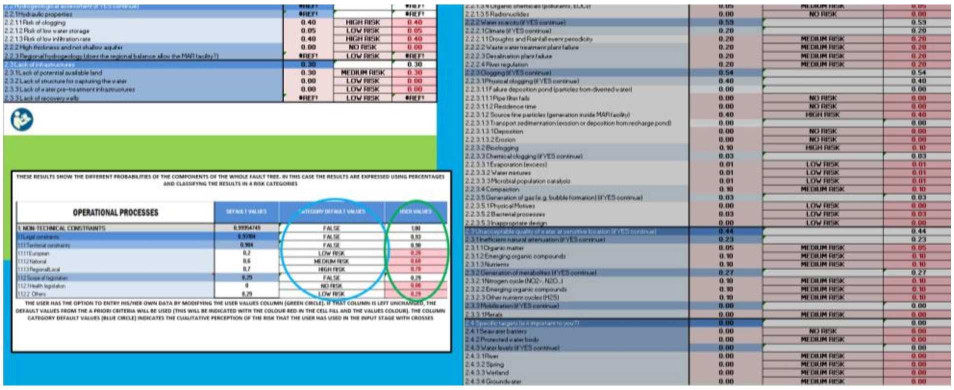


Figure S3.9. Results (bottom part) sheet visualization.

The fourth step of the MAR-RISKAPP is the graphical results (Figure S3.10), displaying the numerical results shown in the previous step into graphs and tables. This step is divided into four points: 1) Operational pivot-table results (Figure S3.11), 2) Design and construction pivot-table results (Figure S3.12), 3) Operational fault tree (Figure S3.13) and 4) Design and construction fault tree (Figure S3.14). As in the other steps, there is a button with instructions, only if the user needs some help or orientation with the results from this step. For both pivot-tables, the results are structured in four categories of risk (high, medium, low, and no-risk). Inside each category, risk values are displayed in decreasing order (from high to low risk values). Also, both pivot-tables have a button to go back to the graphical results main sheet. For both fault trees, each point from the survey is presented by using a rectangle. For each point, risk value is showed on the bottom-left part of the rectangle and also is colored according to risk categories. Finally, both fault-trees have a button to go back to the graphical results main sheet and a button to print the fault tree in a PDF file.

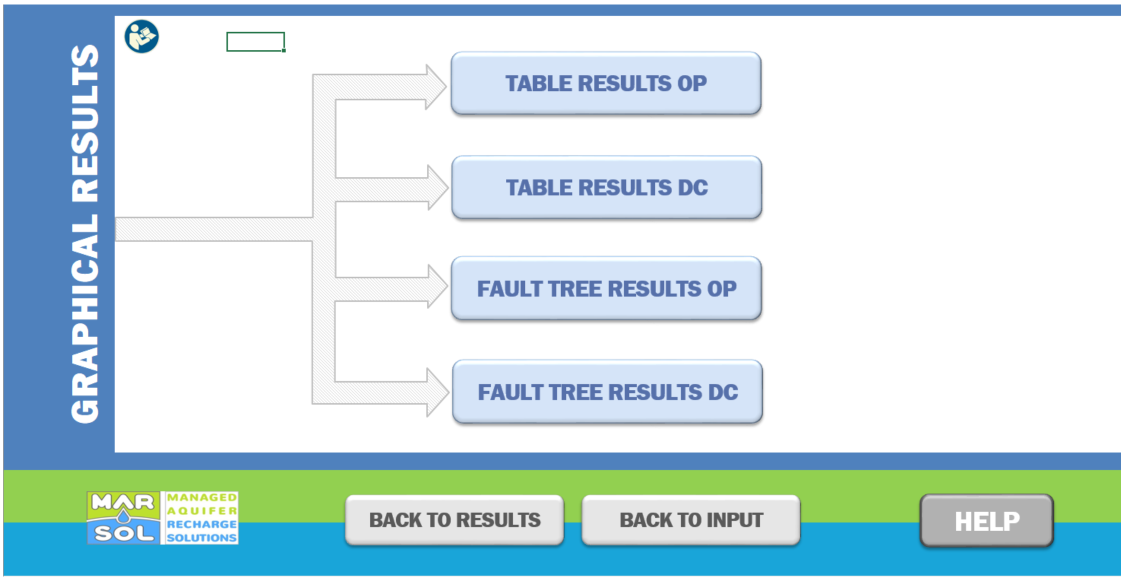


Figure S3.10. Graphical results sheet visualization.

BACK TO GRAPHICAL RESULTS

MAR SOL MANAGED AQUIFER RECHARGE SOLUTIONS

RISK PERCEPTION vs CALCULATED FAILURE RISK

HIGH RISK	
2.2.3.1.2 Source fine particles (generation inside MAR facility)	4.00E-01
1.4.1 Lack of coordination	4.00E-01
2.2.1.2.1 Turbidity/particles	4.00E-01
1.3.4 Children surveillance	3.00E-01
1.3.5 Fair distribution of treated water	3.00E-01
2.2.3.2 Bioclogging	1.00E-01
MEDIUM RISK	
1.3.2 High cost perception	1.00E-01
1.2.2.3 Lack of private/public funding	1.00E-01
2.2.3.4 Compaction	1.00E-01
1.3.6 Perception of effectiveness	1.00E-01
1.3.3 Behavioral requirements	1.00E-01
1.3.1 Health risk perception	1.00E-01
1.2.2.1.2 Agricultural use	5.00E-02
2.2.1.3.4 Organic chemicals (pollutants, EOCs)	5.00E-02
1.2.2.1.1 Industrial use	5.00E-02
1.2.2.2.2 High installation cost	5.00E-03
1.2.2.2.1 Low price of water	5.00E-03
LOW RISK	
1.1.1.1 European	5.00E-02
1.1.2.2 Others	5.00E-02
2.1.3 Terrorism activities/Vandalism	5.00E-02
2.3.2.3 Other nutrient cycles (H2S)	5.00E-02
1.1.1.3 Regional/Local	5.00E-02
2.3.2.2 Emerging organic compounds	5.00E-02
2.1.4.2 Pipe breakage	5.00E-02
2.3.2.1 Nitrogen cycle (NO2-, N2O...)	5.00E-02
1.2.1 Macroeconomic constraints	5.00E-02

Figure S3.11. Operational pivot-table results sheet visualization.

BACK TO GRAPHICAL RESULTS

RISK PERCEPTION vs CALCULATED FAILURE RISK

MEDIUM RISK	
1.4.1 Lack of coordination	1.00E-01
1.2.2.2.1 Low price of water	5.00E-02
NO RISK	
1.2.2.1.1 Industrial use	0.00E+00
1.3.3 Behavioral requirements	0.00E+00
2.1.2.2.1 Droughts and Rainfall event periodicity	0.00E+00
2.3.2 Lack of structure for capturing the water	0.00E+00
1.2.2.2.3 High maintenance cost/maintenance requirements	0.00E+00
2.3.1 Lack of potential available land	0.00E+00
1.1.1.3 Regional/Local	0.00E+00
2.2.3 Regional hydrogeology (does the regional balance allow the MAR facility?)	0.00E+00
1.3.5 Fair distribution of treated water	0.00E+00
2.2.2 High thickness and not shallow aquifer	0.00E+00
1.3.1 Health risk perception	0.00E+00
2.2.1.3 Risk of low infiltration rate	0.00E+00
1.2.2.1.3 Domestic use	0.00E+00
2.2.1.2 Risk of low water storage	0.00E+00
1.1.2.2 Others	0.00E+00
2.2.1.1 Risk of clogging	0.00E+00
1.1.1.1 European	0.00E+00
2.1.3 Right of access	0.00E+00
1.3.6 Perception of effectiveness	0.00E+00
2.1.2.4 Availability of water from desalination plant	0.00E+00
1.3.4 Children surveillance	0.00E+00

Figure S3.12. Design and construction pivot-table results sheet visualization.

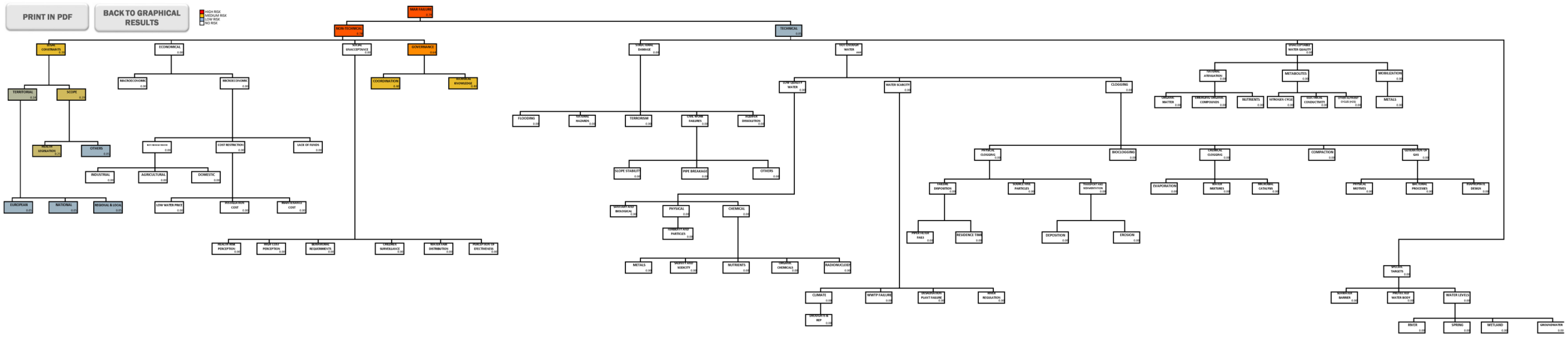


Figure S3.13. Operational fault-tree results sheet visualization.

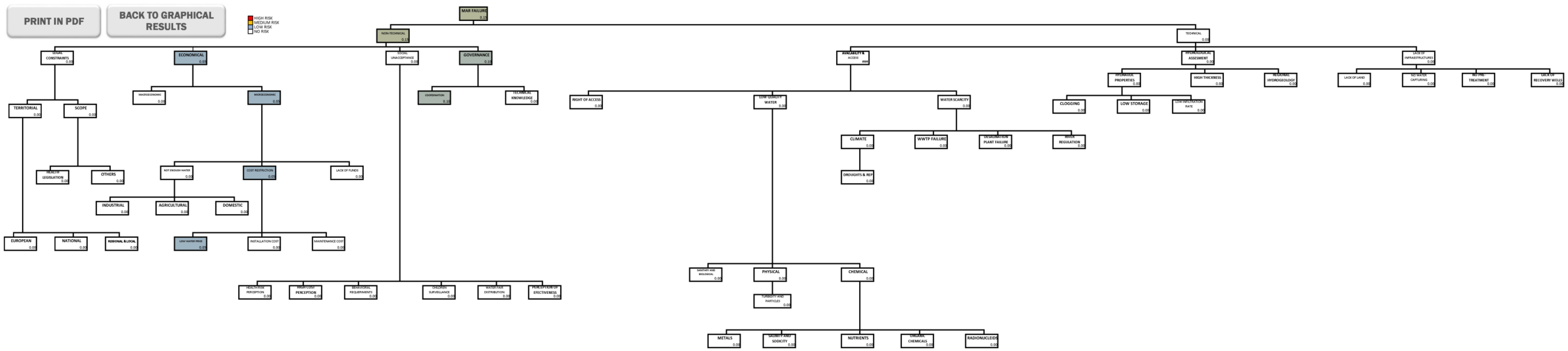


Figure S3.14. Design and construction sheet visualization.