Evaluating the potential of road rain water harvesting in Yemen– Rural Roads

A case study: A case study of the Maghrabah Manakah Bab Bahil Road,Sana'a Governorate

تقييم إمكانيات حصاد مياه الأمطار من الطرق الريفية في اليمن

دراسة حالة لمشروع طريق مغربة مناخة – باب باحل وطريق جبل العوي – محافظة صنعاء

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Problem statement

- Water scarcity, limited water resource and climate change is the main problems facing Yemeni farmers.
- The challenge is how best to control and manage the replenishment and depletion of groundwater resources by improving water harvesting and raise the efficiency in water use.

- Some of Yemen roads were located in mountainous rural areas; which had an adapted design for each environment -In Yemen surface water is estimated to be about 1,500 Mm3/year - Meanwhile, some roads is prone to severe damages and soil erosion as a result of floods events throughout the country in rainy season.

- Manakha area as many of Yemen areas face recurrent droughts, and lack of green cover, where rainwater is the sole source of water, which exist annually in two seasons summer and autumn with an average of 400 mm,
- RRWH is not considered by road engineers during the design, construction and O&M

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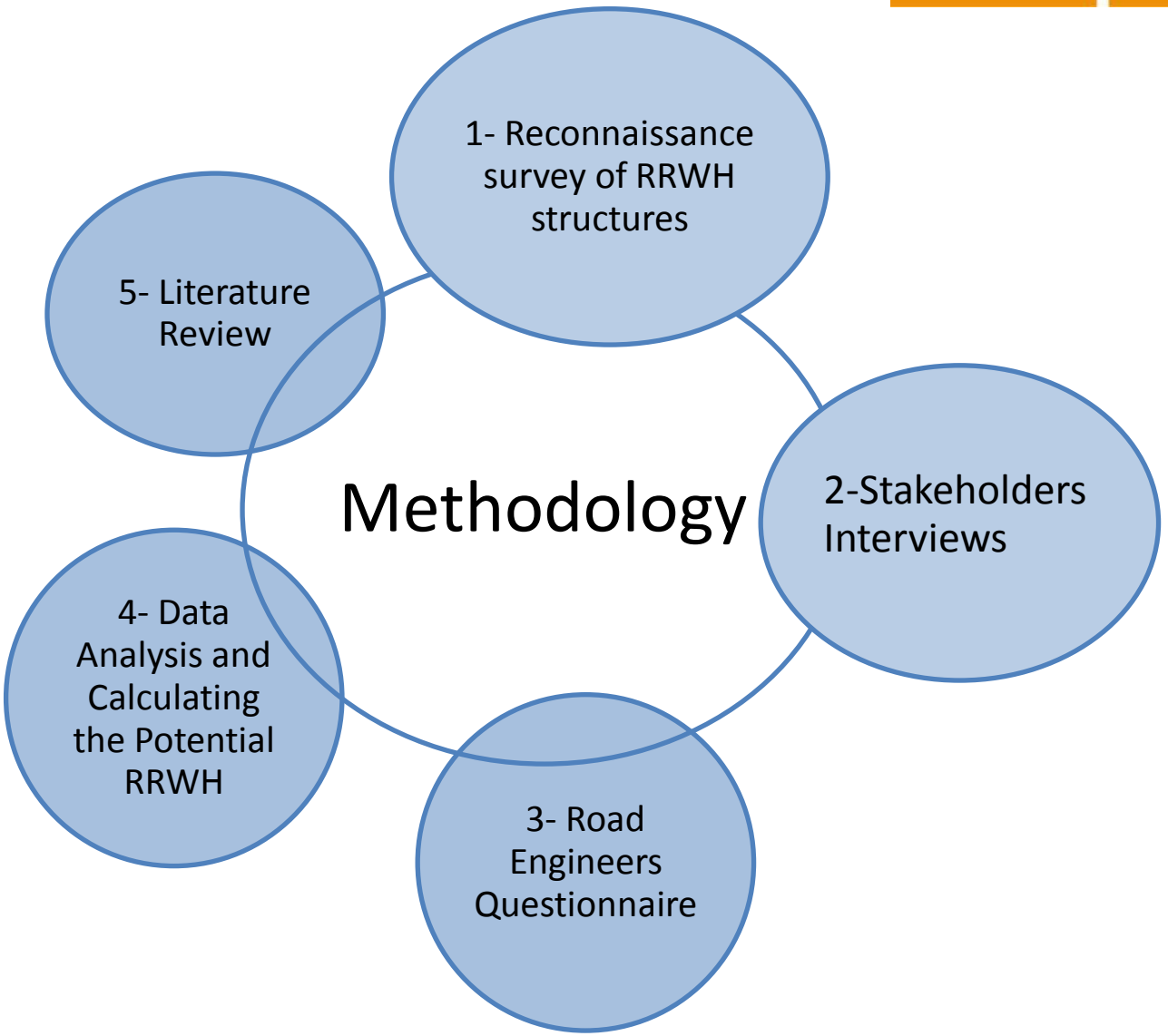
Objective of the research

Main Objectives

Optimize the benefits of water harvesting from roads for the local communities in socio-economic development and for the environment protection focusing on the rural road (Maghrabah Manakah Bab Bahil Road and the linked road Jabal Ekbari and Jabal Awi Road Sana'a Governorate)

SUB- objectives

- To suggest alternative solutions in geometric road designs to manage water from roads due to Integrated Water & Roads Management.
- To induce the awareness of roads engineers on the importance of Integrated Water & Roads Management.


1- Reconnaissance survey of RRWH structures
2-Stakeholders Interviews
3- Road Engineers Questionnaire
4- Data Analysis and Calculating the Potential RRWH
5- Literature Review
Methodology

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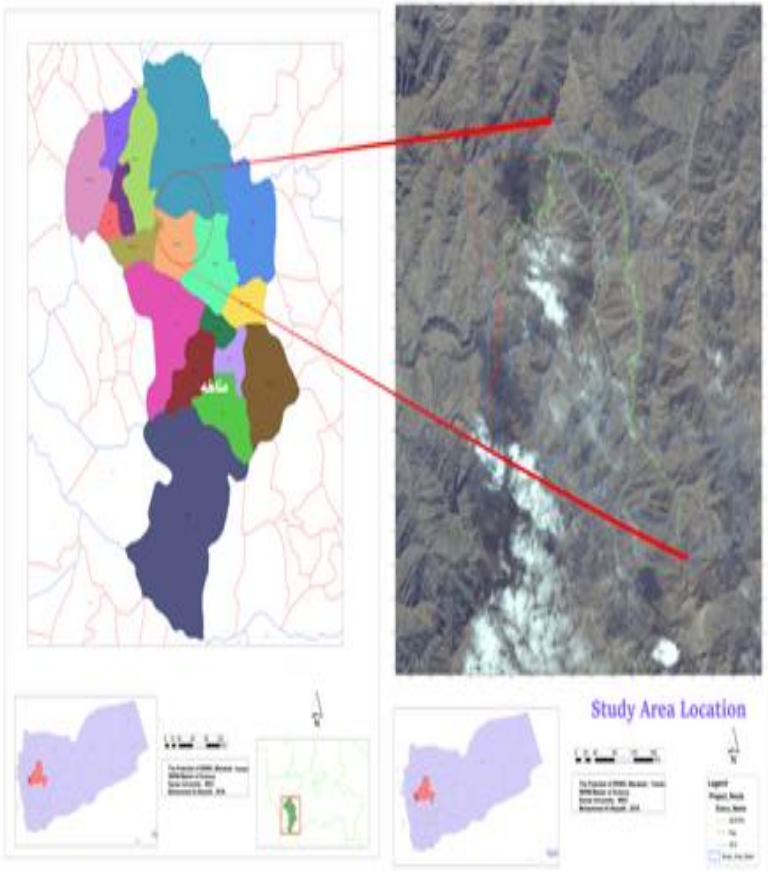
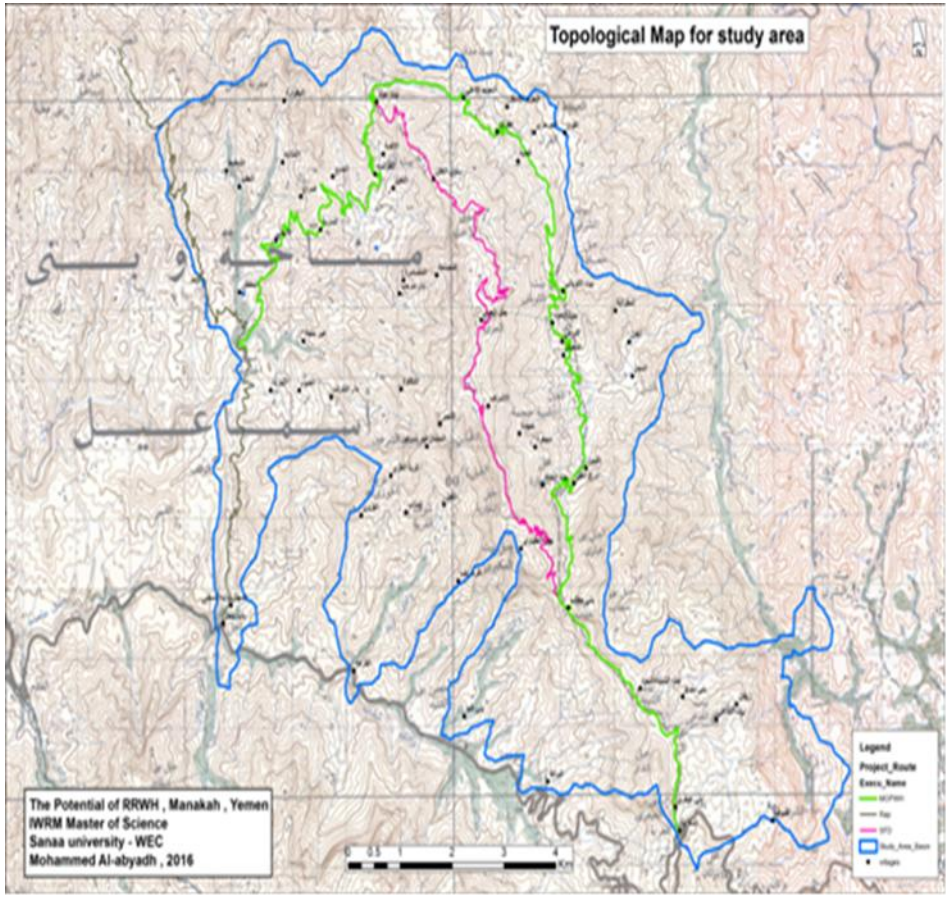
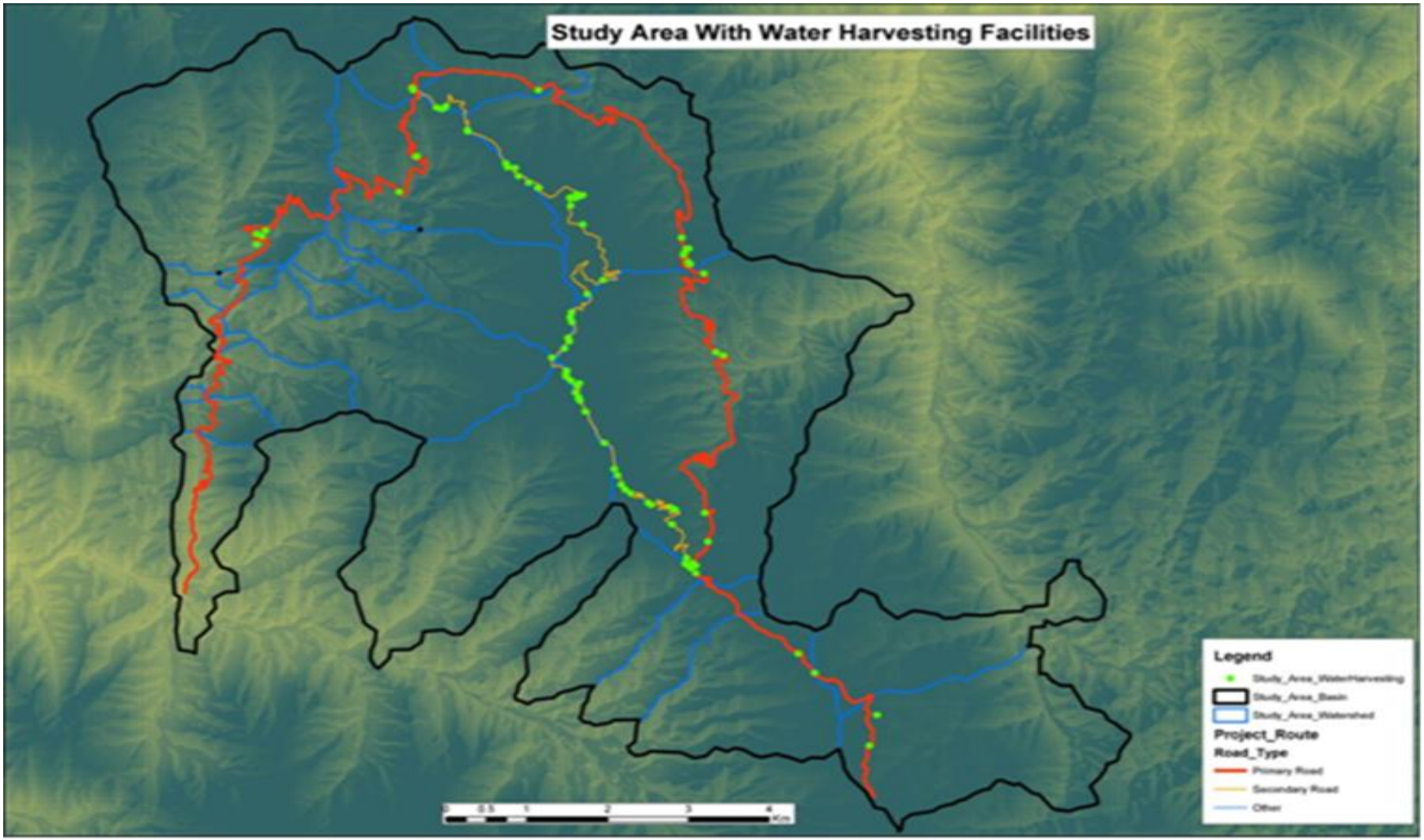
Study Area and Study Road Sections





Results

1- Reconnaissance survey of Road Rainwater Harvesting structures



Results

1- Reconnaissance survey of Road Rainwater Harvesting structures

Item	Main Road	Sub-Road
Open Tanks Ponds	14	12
Roofed Tanks	14	21
Under Construction Tanks	3	3
Cisterns	2	19
Under Construction Cisterns	0	2
Total RRWH Structures	33	57

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- **Results**

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- **Results**

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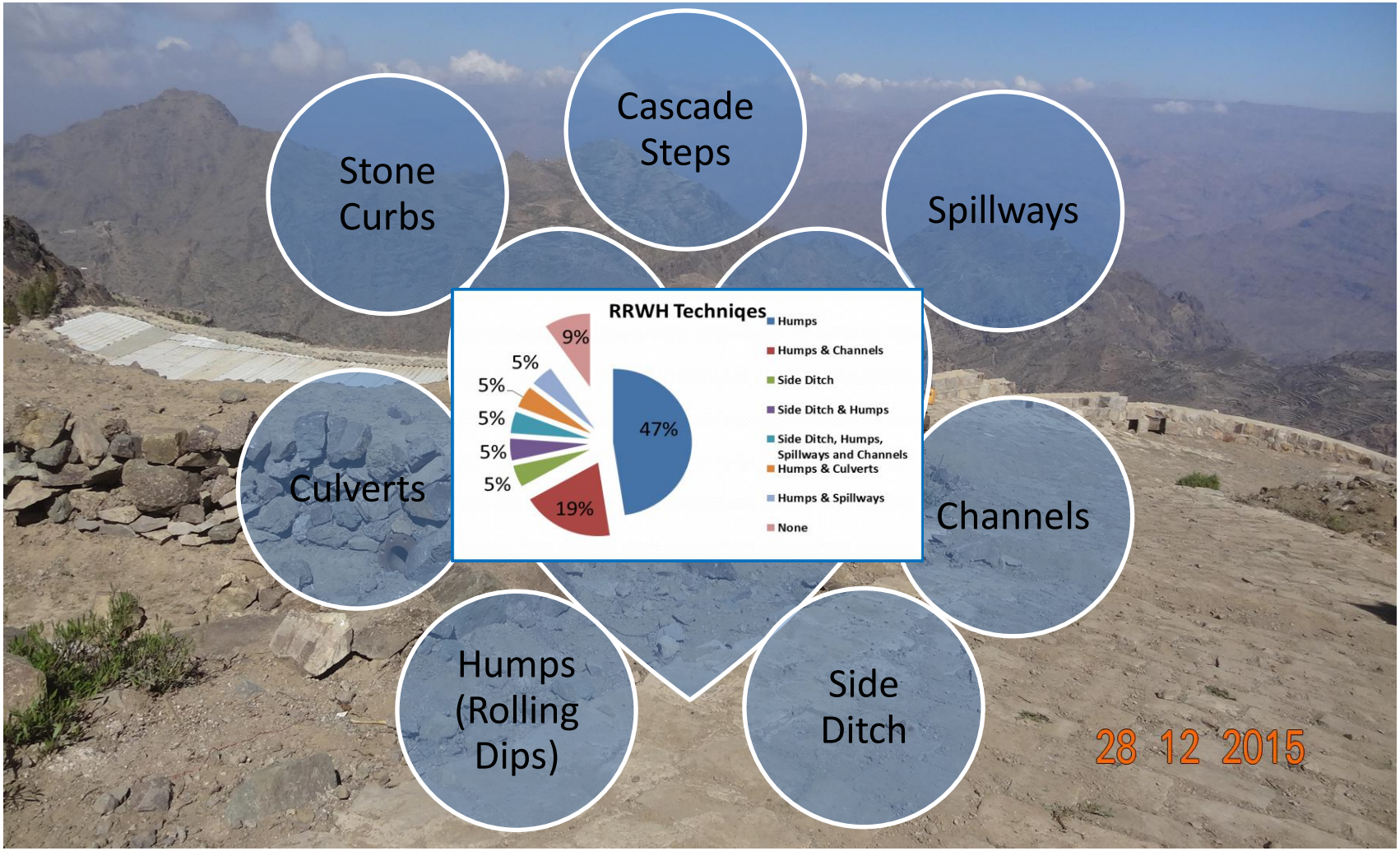
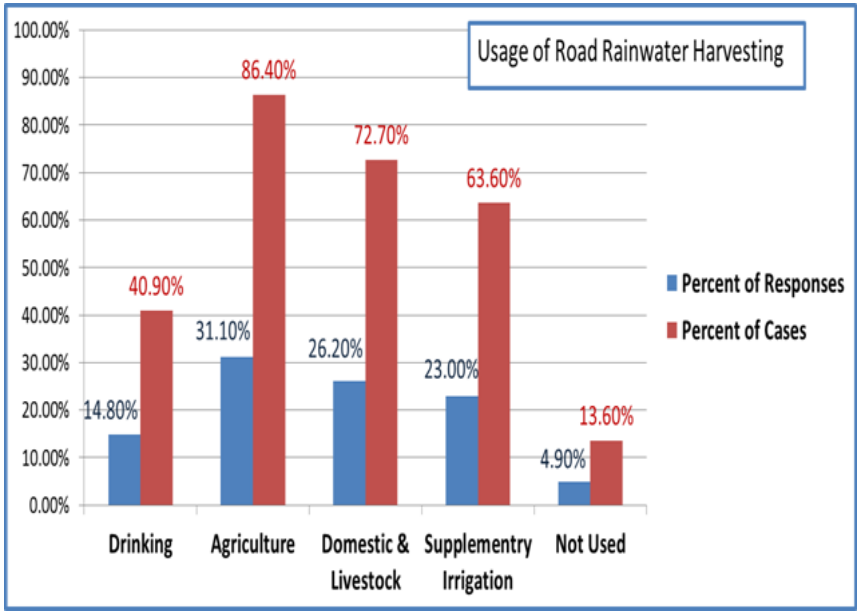
Results

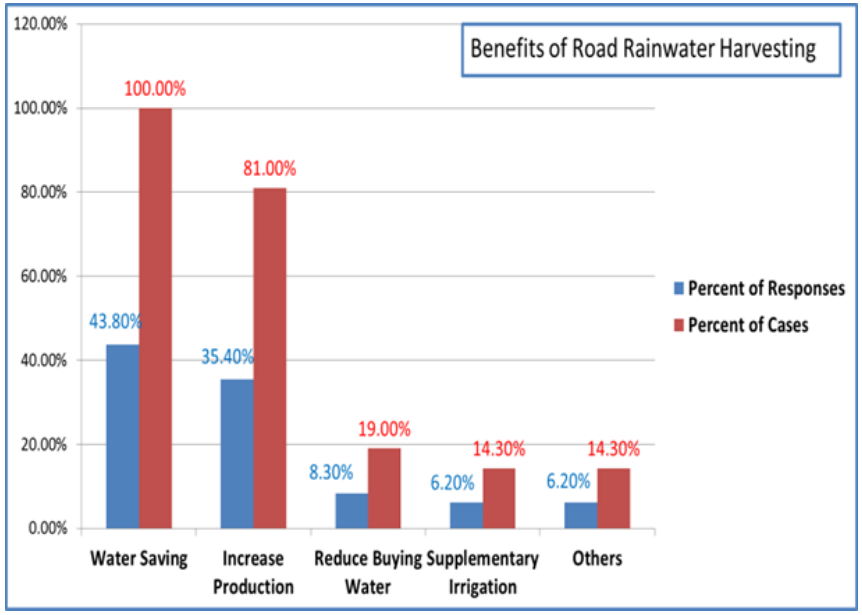
2- Stakeholders Interviews Analysis



Results

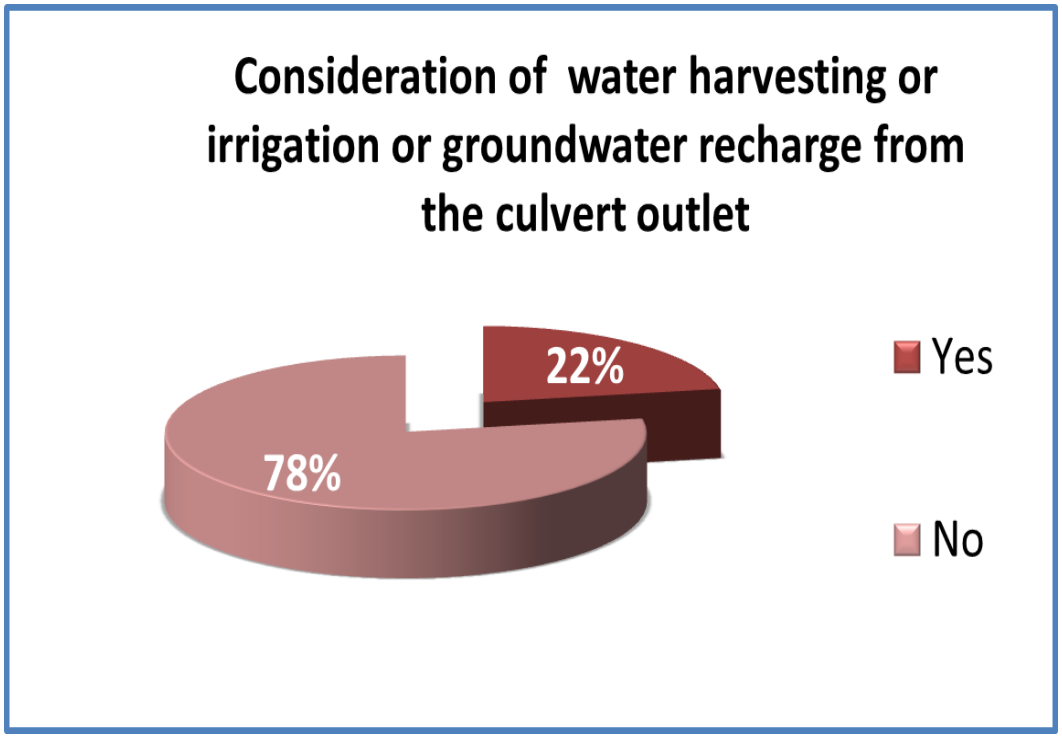
2- Stakeholders Interviews Data Collection and Analysis





3. Road Engineers data Result and Analysis

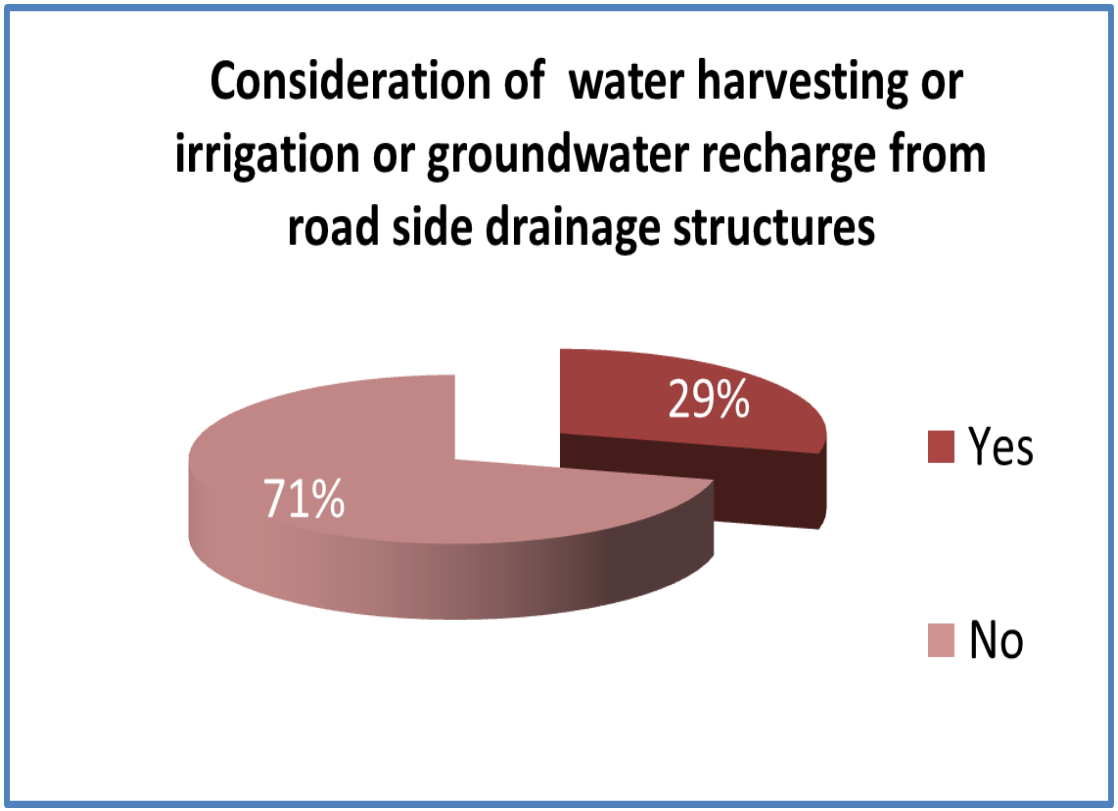
3.1Water harvesting for irrigation or groundwater recharge from the culvert



Only 22% of respondents engineers considered water harvesting for irrigation or groundwater recharge from the culvert outlet.

3. Road Engineers data Result and Analysis

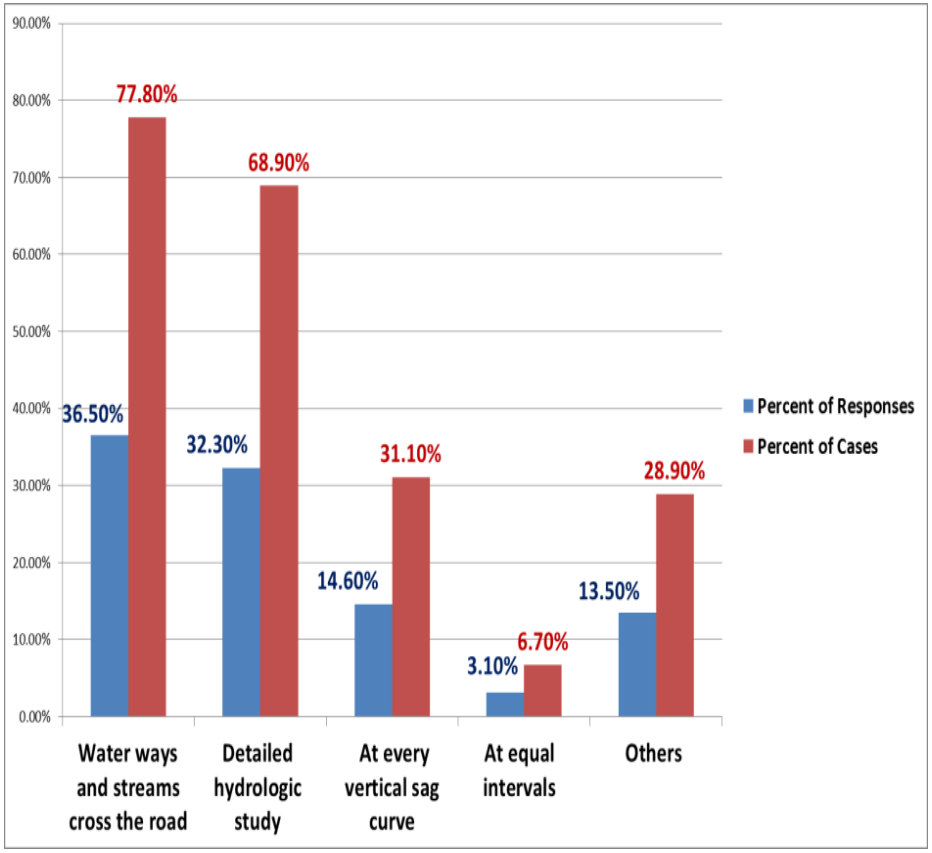
3.2 Water harvesting for irrigation or groundwater recharge from road side drainage structures:



Only 29 % considered water harvesting for irrigation or groundwater recharge from road side drainage structures

3.3 Current culvert design understanding

3.3.1 Location of culverts



The multiple response of the questionnaires were 96 out of 45 case.

Other consideration:

1-Beneficiary participation.

2- If obligated by stakeholders.

3-Design engineer and the nature of the site.

4-Land survey and calculating the catchment area.

5-If the level of the road is higher than the wadi level.

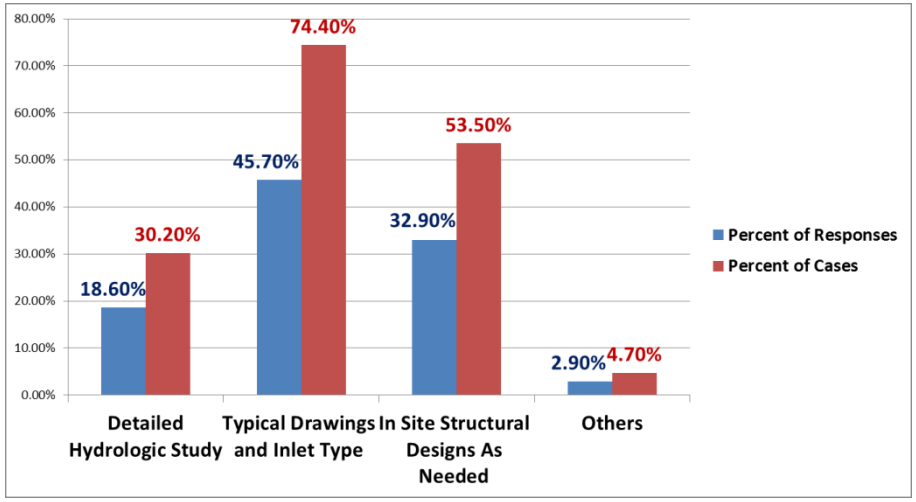
6-In international projects due to detailed hydrologic study.

7-At every vertical sag curve if there is no side drain.

8-If needed to transform water from side to side.

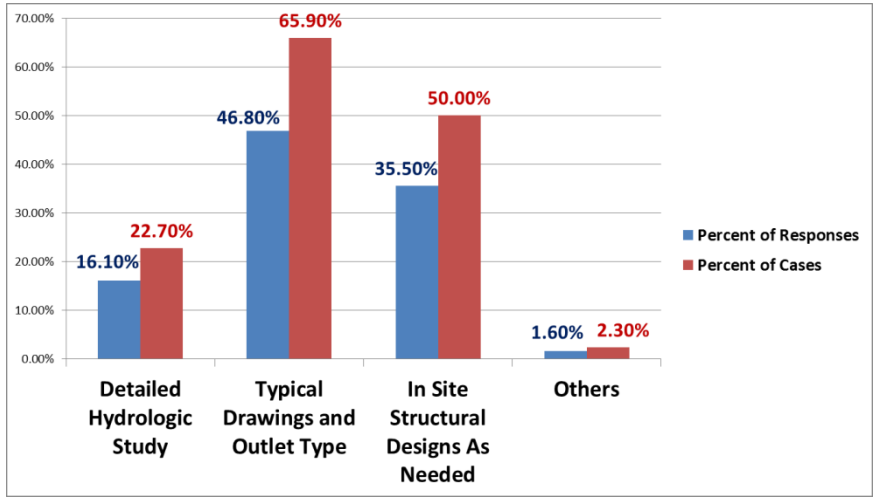
9-In multi curves sections in mountainous roads to alleviate the accumulated water from the ditches.

3.3.2 Culvert Inlets Design



The multiple response of the questionnaires were 70 out of 45 case.

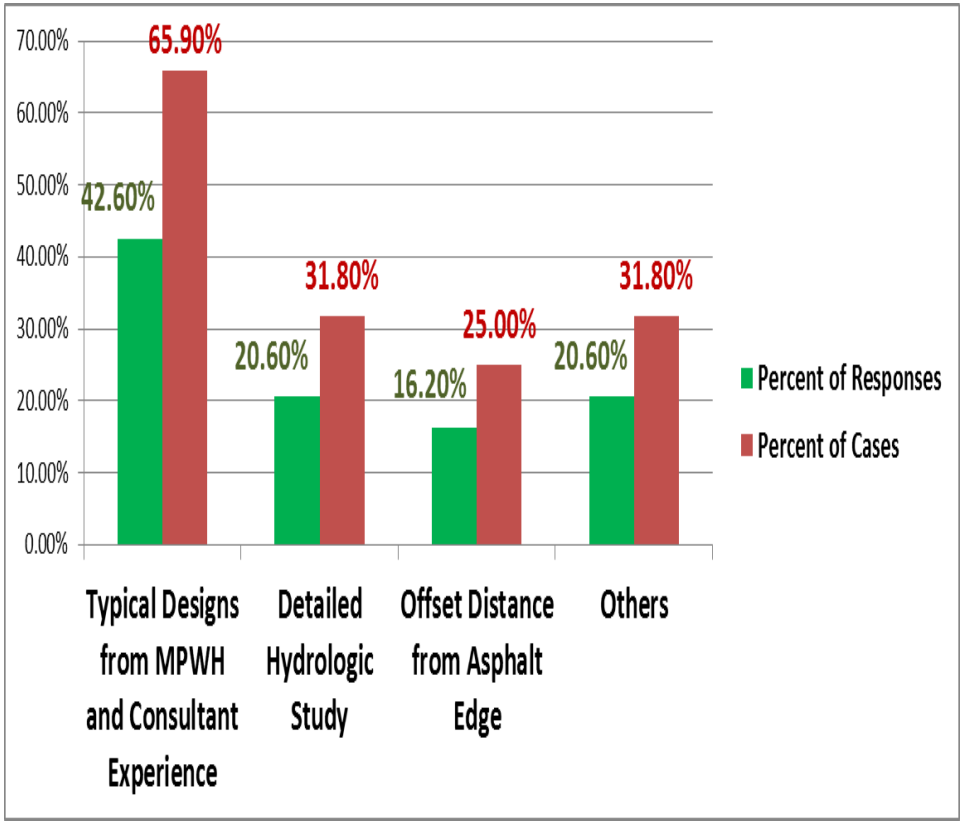
3.3.3 Culvert Outlets Design



The multiple response of the questionnaires were 62 out of 44 case.

3.4 Ditches design

3.4.1 Dimension & shape of side ditches



The multiple response of the questionnaires were 68 out of 44 case.

Other consideration:

1-According to the nature of the catchment area above the ditch.

2-According to the estimated amount of flow water .

3- Nature of the region, type of cut section or the outer edge (rock, steep), road longitudinal slope and road classification.

4-adoption of typical, and prepare hydrological studies and hydraulic detailed calculations.

5-To ensure that there is no erosion of the road.

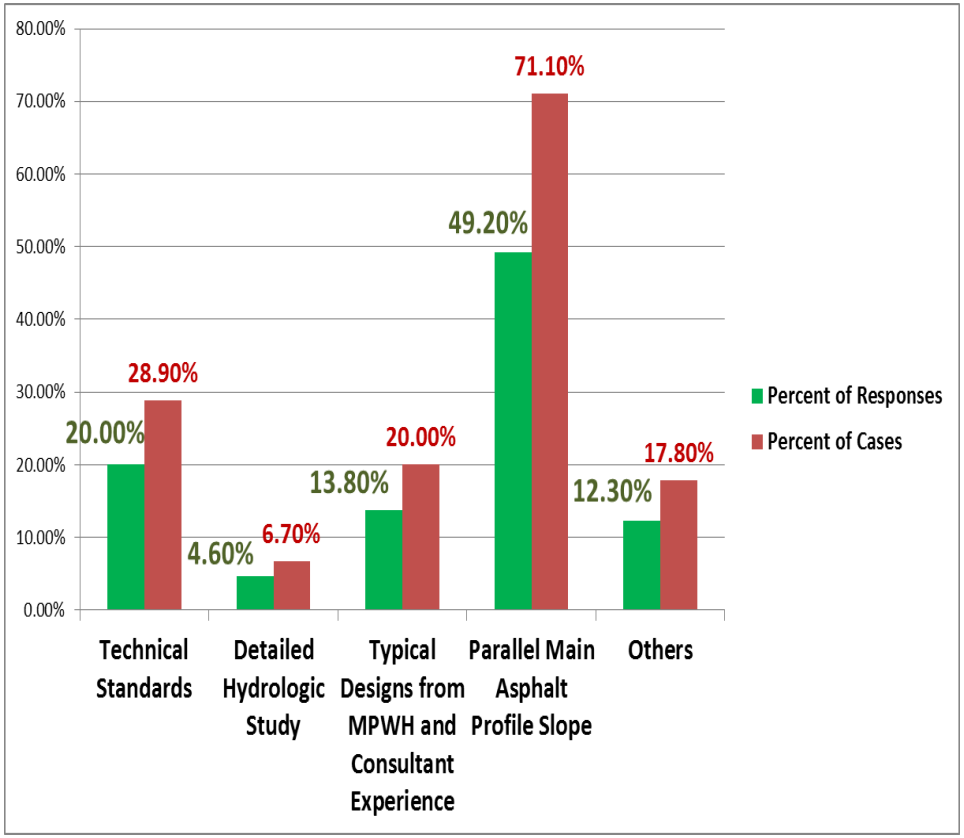
6-In the absence of a suitable typical , the MOPWH is reviewed and prepare appropriate suggestion to be implemented and protect the road.

7-According to economic view beside the shape and size of the landscape.

8-In most roads it is defined according the available width after the cut excavation.

9- The Shape is preferably a trapezoid or triangle.

3.4.2 The longitudinal slope of ditches



The multiple response of the questionnaires were 65 out of 45 case.

Other consideration:

1-In locations of water accumulation near villages closed side drainage channels were designed with detailed drawings.

2-Sometimes uplift rock were used in the ditch to reduce the velocity.

3-Depending on the nature of the site.

4-According to asphalt slopes , especially when there are sections near houses.

5-Longitudinal slopes depend on subgrade slopes and cross section slope such as superelevation and widening.

6-According to a quick on-site study and make at site decision.

7-According to the longitudinal profile slopes.

8-Constrain of minimum/required slope for discharge.

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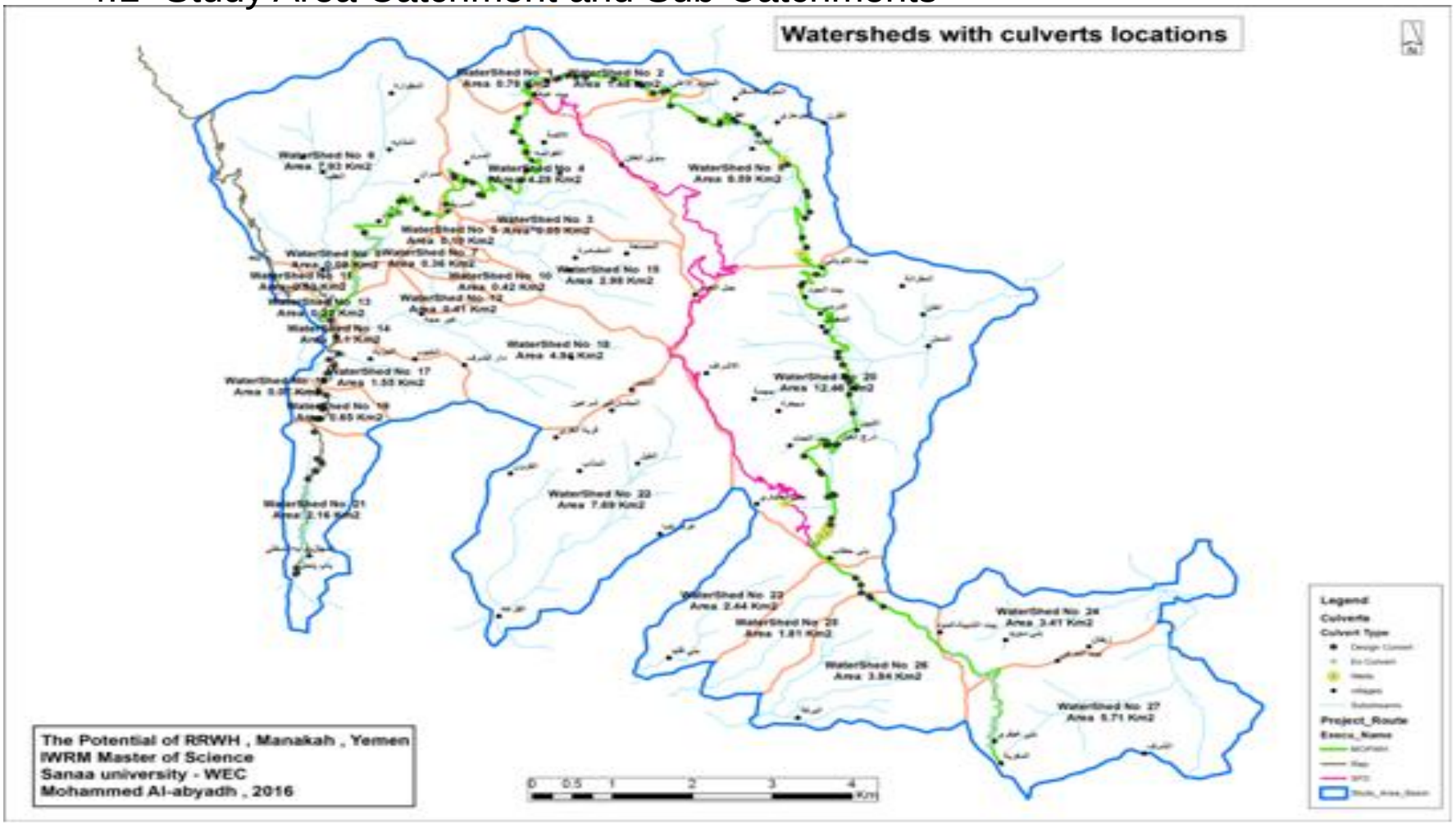
4- Potential of road rainwater harvesting

4.1- Study Area Catchment and Sub-Catchments



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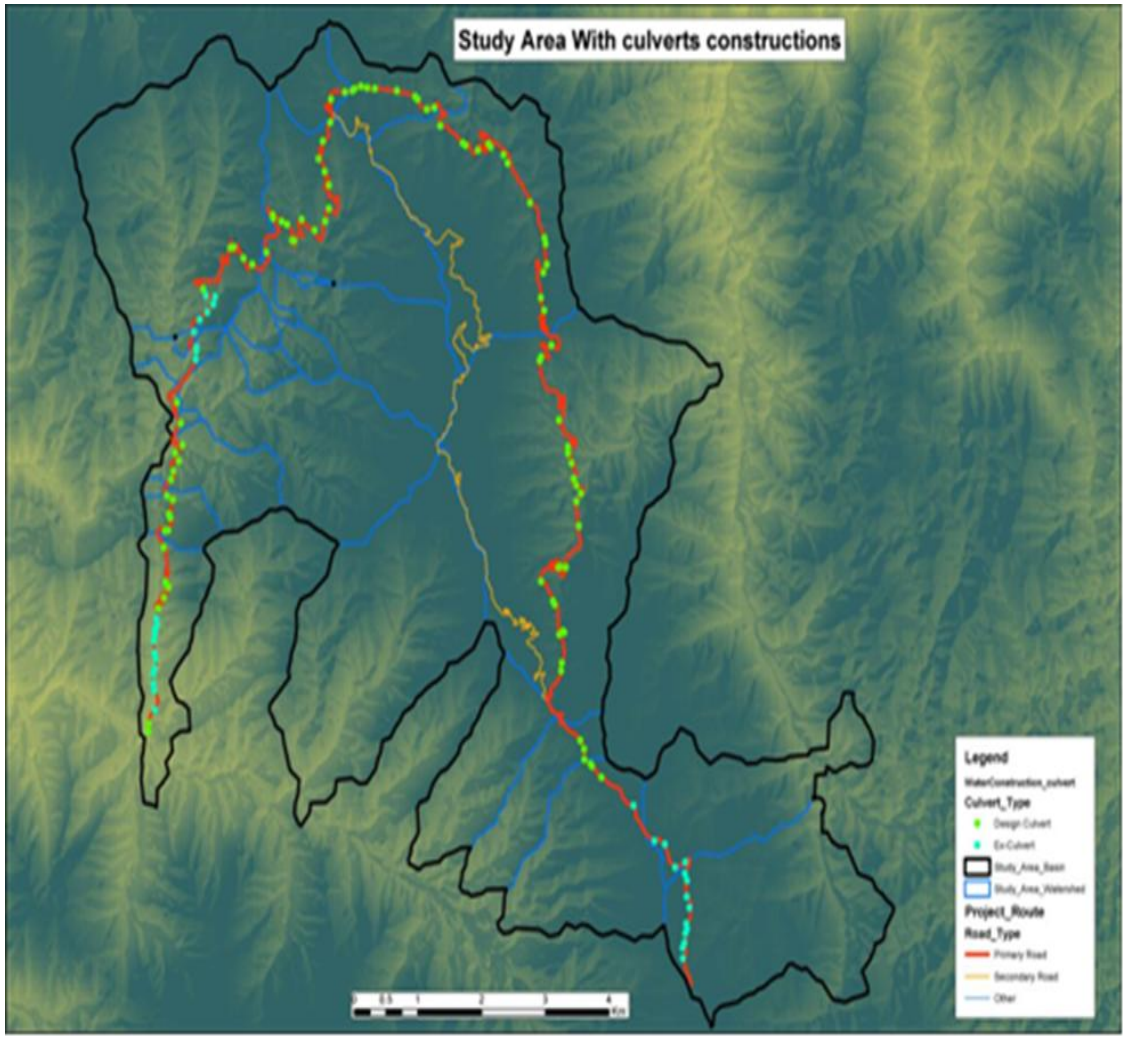
4.2- Culverts location along the main study road



No.	Sub-Catchment Category	Sub-Catchment Area (Km2) (1)	Road Natural Catchment Area (Km2) (2)	Percentage of (2) from (1)	No. of Culverts	Culvert Type
1	27	5.71	0.38	6.65%	10	Executed
2	24	3.41	0.11	3.23%	4	Executed
3	26	3.84	0.26	6.77%	4	1 Executed / 3 Design
4	25	1.81	0.22	12.15%	3	Design
5	20	12.46	2.54	20.39%	23	Design
6	9	6.59	2.86	43.40%	15	Design
7	2	1.48	0.36	24.01%	10	Design
8	1	0.78	0.09	11.54%	2	Design
9	4	4.28	0.64	14.95%	16	Design
10	6	7.93	0.66	8.32%	10	5 Executed / 5 Design
11	8	0.08	0.02	25.00%	1	Executed
12	11	0.53	0.16	30.19%	3	Executed
13	13	0.22	0.02	8.00%	1	Design
14	14	0.1	0.07	70.00%	1	Design
15	17	1.55	0.31	20.00%	5	Design
16	19	0.65	0.49	75.38%	6	Design
17	21	2.16	0.66	30.56%	19	12 Executed / 7 Design
Total		53.58	9.85	18.38%	133	

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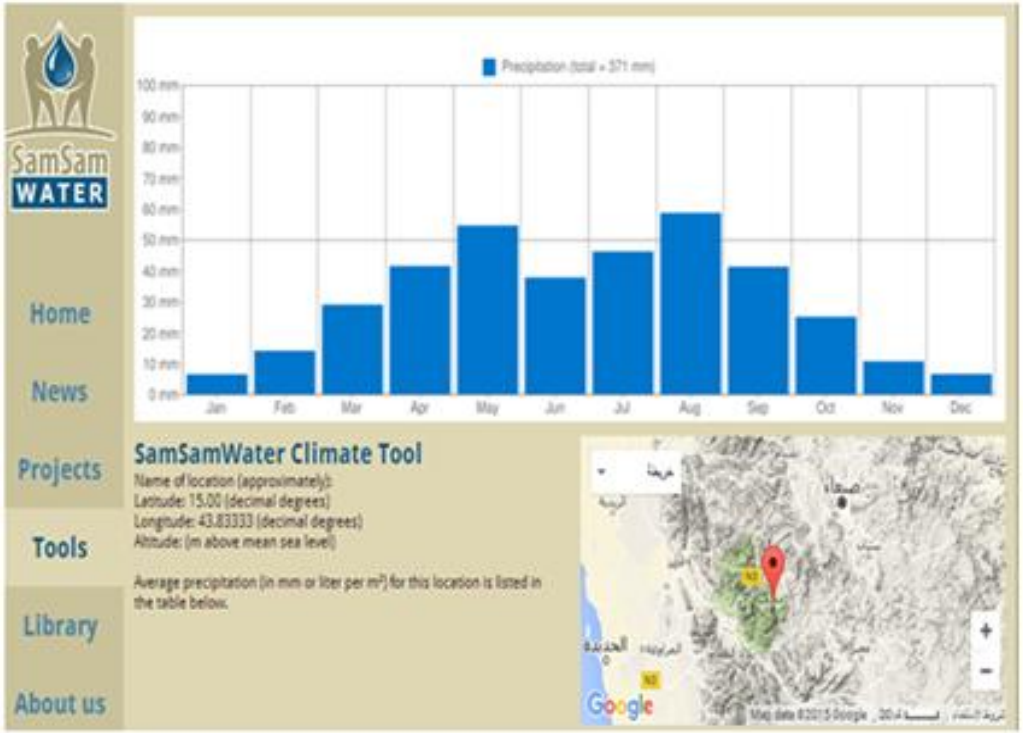
4.3 - Main Road Natural Catchments Area …

The road natural catchment area is 9,85 km^2 it represent a 18.38 % percent of the total study watershed sub catchments area which is 53.58 km^2.

4.4 – Assumptions and Formula



Month	Rainfall (mm)
January	6
February	14
March	29
April	41
May	55
June	38
July	46
August	59
September	41
October	25
November	11
December	7
Year	371

Source of data: CRU CL 2.0 which is described in New, M., Lister, D., Hulme, M. and Makin, I., 2002: A high-resolution data set of surface climate over global land areas. Climate Research 21:1-25 and Aquastat.

- Runoff coefficient K = 0.65 & Efficiency Factor E = 0.7

Water Harvested (m^3) = Catchment Area (m^2) * P_d (m) * K * E

Conclusions

- The estimated potential RRWH quantity from the main road surface is 60,769. 8 m3 for 36 km length and 10 m width, while the potential RRWH which generated from the road natural catchment is (9.85 Km2) 1,662,729.25 m3 .

- The RRWH locations were observed at the culverts outlets, humps (rolling dips) , channels, spillways, cascade steps and at the inner side of the road .

- The culverts catchment and outlets type vary according to the land use of the surrounding area, the landscape slope,. Moreover, the culverts catchment could be a sub-catchment, stream line, sub-stream or from the upper road section, while the culvert outlet could be a sub-catchment, stream line, sub-stream, road section, terraces, steep slope and tanks.

Conclusions

- All farmers consider rainwater running on the road their right.

- During road construction some claims raised by farmers such as: abandon water channels, water blockage, transmit sediments to farmlands, erosion, use of dynamite, road profile falling down farmland level and lack of communication with engineers.

- Several public and private tanks and ponds where used to harvest rainwater from road which need to give more attentions from locals in periodic maintenance for these structures.

Conclusions

- Engineers have practiced a number of possible drainage design procedures and consideration to the general road drainage structures such as culverts, ditches. However, the differences in road design are often forced by changes in geology & terrain, experience, use of typical drawings, lack of hydrologic and hydraulic studies, absence of integrated water resource approach, and cost restraint.

- More than half of Engineers response used typical drawings from MPWH in drainage structures.

- Some road geometric parameters such as vertical alignments, camber and (cross-slopes or superelevation), had effect on road drainage and consequence the rainwater harvesting system.

- Numbers of manuals mentioned the road rainwater harvesting in different ways and techniques, those ways and techniques should be generalized.

Recommendation

- Farmer's initiatives should be encouraged and improved technically and institutionally, and also should be supported from government's agencies and donor programs.

- The RRWH should be adapted by taking advantage of previous experience locally and across the World.

- Water rights along the road and in the downstream catchment should be considered to avoid social conflicts in case of RRWH.

- Capacity building for road engineers in integrating road design with RRWH.

- Social communication mechanism between engineers and stakeholders should be developed in all road projects in all phases.

- MPWH typical drawing should be updated and reviewed according to Yemen Hydrologic studies and RRWH integrated approach.

Recommendation

- Staged co-financed integrated approach (design and implementation) is suggested to cope with the cost factor (taking advantage of road construction equipment's) to achieve the sustainable rainwater harvesting in the road vicinity.

- A Careful consideration of coordination and combination the horizontal and vertical alignments and drainage structures with reference to road catchment and natural drainage pattern which may be best indicated by:

1. Contoured drawings of the required carriageway surface with water stream lines, culverts locations, land use map and potential RRWH locations.

2. Details drawings of drainage structures (culverts, ditches, etc..) plan and profile especially when the cross section changed from cut to fill and at the outlet.

- Road drainage structures and protection works in roads should take in consideration rainwater harvesting, water rights, erosion control, environment sustainability and social and gender expectations.

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