PROVISION OF CONSULTANCY SERVICES FOR THE PREPARATION OF A MASTER PLAN FOR THE CLOSURE AND REHABILITATION OF UNCONTROLLED DUMPS THROUGHOUT THE COUNTRY OF LEBANON

FINAL REPORT

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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EXECUTIVE SUMMARY

ELARD has been contracted by the UNDP/MoE to prepare a Master Plan for the Closure and Rehabilitation of Open and Uncontrolled Dumps in Lebanon. The Master Plan aims at:

- Establishing a comprehensive database of all Municipal Solid Waste (MSW) and Construction and Demolition Waste (CDW) dumps over the Lebanese territory[1];
- Prioritizing identified dumps in terms of necessity for rehabilitation;
- Identifying most suitable rehabilitation methods for each dump and developing an action plan for its rehabilitation and/or closure.

The present report describes the methodology followed for the Master Plan preparation and summarizes its main findings and proceedings.

1. SURVEY AND DATABASE GENERATION

Three teams of surveyors, each composed of a Geologist and an Environmental Scientist, were mobilized to locate and survey all open and uncontrolled dumps in Lebanon. Survey teams proceeded by Caza, screening all municipalities and villages for possible dumps and contacting them for on-site meetings.

At the end of each field visit, a large set of data characterizing the dumpsite was collected and entered into a digitalized Characterization Form. Coordinates and surface area were measured using a GPS, and pictures of the dump and its surroundings were taken. All collected data was regularly communicated to both the GIS and the Solid Waste Experts for QA/QC.

A total number of 670[2] dumps were identified and surveyed over the Lebanese Territory (Table 1). The completed characterization form was then transferred into a GIS based format, which allows the user to view and compare all information and pictures related to all dumps.

Table 1 Total Number and Volume of Dumps Identified

	NUMBER	VOLUME (m^3)
MSW Dumps	504	5,004,076
CDW Dumps	166	1,731,180
TOTAL	**670**	**6,735,256**

[1] Were excluded from the survey:
- The Tripoli dump, which has already been rehabilitated;
- The Bourj Hammoud dump, which has been closed since 1997. Additionally, there are plans for turning it into a Wastewater Treatment Plant for Mount Lebanon;
- Controlled waste disposal facilities (the Naameh, Bsalim, Zahle, and Baalback landfills).

[2] This number is subject to change as MSW and CDW dumps are likely to unexpectedly emerge in new locations after the completion of this project.

2. PRIORITIZATION

A Prioritization Decision Tool (PDT) was developed in order to prioritize dumpsites based on a Risk Sensitivity Index (RSI). Two (2) different models were developed to separately address MSW and CDW dumps, as these are characterized by very different features.

For this purpose, ten (10) attributes were selected for MSW dump prioritization, and eight (8) were considered for CDW dumps prioritization. These attributes were each assigned a specific "weight" reflecting the relative significance of their associated environmental impact. Weights ranged from 1 to 10 for MSW dumps, and from 1 to 8 for CDW dumps. Each attribute was then given a "sensitivity grade" varying from 0 to 1 and divided into 4 quarters or ranges (Table 2; Table 3).

Table 2 MSW Dumps Attribute Table

ATTRIBUTE		WEIGHING FACTOR	0.0-0.25	0.25-0.5	0.5-0.75	0.75-1.0
Total quantity of waste at site (m3)		10	<10,000 m3	10,000 - 50,000m3	50000 - 100000 m3	>100,000 m3
Geology	Lithology (70%)	9	Considerable to high clay content	Clay contents and jointing systems	Secondary porosity, different forms of karstification and presence of some marl intercalations	Secondary porosity (cracks & joints) of carbonate rock, plus high karstification
	Faults & lineaments density (segment/km2) (30%)		<10	10-15	15-20	> 20
Hydrology	Distance to drainage line (80%)	8	>200m	200-100m	50-75 m	<50m
	Distance to springs (20%)		>200m	200-150m	150-100 m	<100 m
Distance to urban areas		7	> 1000 m	1000 - 500 m	250 - 500 m	<250 m
Quantity of waste currently dumped at site (t/d)		6	<10 t/d	10-50 t/d	50 - 100 t/d	>100 t/d
Presence of alternatives		5	No Alternatives	Working on alternative solution & funding	Alternative under construction	Alternative operational
Open burning of waste		4	Burned		Not Burned	
Visibility		3	Not visible		Visible	
Depth of filling of waste (m)		2	<1m	1 - 5 m	5-10 m	>10 m
Duration of dump exposure (years)		1	< 10 year	10-20 years	20-30 years	>30 years

Table 3 CDW Dumps Attribute Table

ATTRIBUTE		WEIGHTING FACTOR	0.0-0.25	0.25-0.5	0.5-0.75	0.75-1.0
Volume of waste at site (m3)		8	<10,000 m3	10,000 - 50,000m3	50000 - 100000 m3	>100,000 m3
Visibility		7	Not visible		Visible	
Hydrology	Distance to drainage line (80%)	6	>200m	200-100m	50-75 m	<50m
	Distance to springs (20%)		>200m	200-150m	150-100 m	<100 m
Distance to urban areas		5	> 1000 m	1000 - 500 m	250 - 500 m	<250 m
Presence of alternatives/intended use		4	No alternatives/no plans	Working on alternative solution & funding	Alternative under construction	Alternative operational
Status (Abandoned/Operational)		3	Abandoned		Operational	
Geology	Lithology (70%)	2	Considerable to high clay content	Clay contents and jointing systems	Secondary porosity, different forms of karstification and presence of some marl intercalations	Secondary porosity (cracks & joints) of carbonate rock, plus high karstification
	Faults & lineaments density (segment/km2) (30%)		<10	10-15	15-20	> 20
Duration of dump exposure (yrs)		1	< 10 year	10-20 years	20-30 years	>30 years

The Risk Sensitivity Index (RSI) was then calculated for each dump by adding all attributes after multiplying each sensitivity grade (class) by its weight respectively (Equation 1).

Equation 1

$$RSI = \sum_{n=1}^{n} W_i S_i$$

Where:

W_i: is the weightage of the i^{th} variable ranging from 1-10
S_i: Sensitive index of the i^{th} variable ranging from 0-1
RSI: Risk Sensitivity Index variable ranging from Minimum 0 to Maximum 55

A site with a higher score indicates more risk to human health and the environment, and suggests that it requires a more urgent intervention. Conversely, when the total RSI score of a dumpsite decreases, the priority for its rehabilitation decreases.

A sensitivity analysis exercise was conducted over the PDT model so as to verify and confirm its validity. The model proved to be very stable as a result. It is to be noted though that a rehabilitation plan was suggested to all surveyed dumps regardless of their ranking; the Master Plan as such remains therefore unaffected by prioritization outcomes.

Although the RSI has been calculated for all dumps, only the twenty (20) highest ranked are shown here. These twenty "priority" dumps:

- Form an aggregate volume which represents respectively 70% and 75% of the total volume of MSW and CDW dumps (for MSW and CDW dumps combined, the 40 priority dumps represent 71% of the total volume);
- Cover all dumps comprised in the first range of priority and an additional share of dumps from the second range (around 8% for MSW dumps and 25% for CDW dumps);
- Represent respectively 4% and 12% of total number of MSW and CDW dumps (around 5% in total); and
- Include those dumps with RSI values exceeding respectively 40% and 50% of maximum attainable RSIs for MSW and CDW dumps.

Table 4 20 Highest Ranked MSW Dumps

RANK	DUMP ID	MOUHAFAZA	CAZA	RSI SCORE
1	G-2-Saida	South	Saida	47.49
2	C1-Deir Qanoun El - Aain-01	South	Sour	36.97
3	N5-Hbaline-0	Mount Lebanon	Jbeil	35.12
4	T9-Srar-0	North	Akkar	33.88
5	R7-Adweh-0	North	Minieh	32.64
6	E4-Kfar Tibnit-00	Nabatieh	Nabatieh	32.08
7	J7-Barr Elias-00	Beqaa	Zahle	31.82
8	P5-Hamat-1	North	Batroun	30.54
9	M9-Baalback-02	Beqaa	Baalback	28.25
10	M9-Baalback-01	Beqaa	Baalback	27.74
11	J6-Qabb Elias-00	Beqaa	Zahle	27.05
12	G2-Ghaziye-00	South	Saida	25.98
13	S7-Mqaiteaa-0	North	Minyeh-donniye	25.62
14	R9-Fnaydek-0	North	Akkar	24.40
15	L8-Haouch el Refqa-00	Beqaa	Baalback	23.93
16	L4-Zouk Al Khrab-1	Mount Lebanon	Maten	23.65
17	J5-Rouayset El Ballout-0	Mount Lebanon	Baabda	23.57
18	K7-Timnine-00	Beqaa	Baalback	23.41
19	R8-Birkayel-0	North	Akkar	23.17
20	P7-Beslouqit-2	North	Zgharta	22.66

Table 5 20 Highest Ranked CDW Dumps

RANK	DUMP ID	MOUHAFAZA	CAZA	RSI SCORE
1	L8-Chmestar-01	Beqaa	Baalback	27.34
2	I4-Ammiq Ech Chouf-0	Mount Lebanon	Shouf	21.84
3	I4-Dmit-0	Mount Lebanon	Shouf	21.46
4	K4-Beit Meri-00	Mount Lebanon	Metn	21.35
5	B-3-Kounine-02	Nabatieh	Bent Jbeil	21.02
6	L4-Mtayleb-1	Mount Lebanon	Metn	20.98
7	K5-Mar Moussa Ed-Douar-0	Mount Lebanon	Metn	20.35
8	L5-Aain Er-Rihane-3	Mount Lebanon	Kisirween	20.08
9	L5-Qlaiaat-3	Mount Lebanon	Kisirween	19.88
10	L4-Zouk Al Khrab-2	Mount Lebanon	Metn	19.52
11	L4-Dik Al-Mahdi-0	Mount Lebanon	Metn	19.38
12	I5-Maaser Ech Chouf-0	Mount Lebanon	Shouf	19.28
13	E-5-Chebaa-01	Nabatieh	Hasbaya	18.62
14	L4-Zouk Mousbeh-7	Mount Lebanon	Kisirween	18.55
15	I4-Aatrine-1	Mount Lebanon	Shouf	18.22
16	L4-Zouk Al Khrab-4	Mount Lebanon	Metn	18.22
17	L4-Zouk Al Khrab-3	Mount Lebanon	Metn	18.21
18	M5-Kfar Yasine-0	Mount Lebanon	Kisirween	18.11
19	J5-Chbaniye-0	Mount Lebanon	Baabda	18.09
20	J4-Aaytat-0	Mount Lebanon	Aalay	17.91

An easy access GIS interface was created to allow running the Risk Sensitivity Index (RSI) for both MSW and CDW dumps. Users are given the option to change the weighing factor for each parameter.

Codes were also developed to enable symbolizing and classifying the dumps according to their RSI score. Finally, a help button displays different forms guiding the user through the interface model.

3. REHABILITATION

Remedial measures differ from one dump to the other based on the complexity of the case and the availability of alternative waste management solutions.

Seven remedial measures were considered for MSW dumps, namely:

1. Excavate, treat and transfer waste to waste treatment /sanitary landfill;
2. Transfer to a sanitary landfill/controlled dump;
3. Convert to a controlled dump or to a sanitary landfill;
4. Excavate, treat[3], and transfer;
5. Grade, cap and manage gases;
6. Grade, cap and manage gases and leachate; and
7. Group with other dumps and transfer to controlled dump.

Additionally, four remedial measures were considered for CDW dumps, consisting of:

1. Sorting, crushing and recycling;
2. Transfer to other priority dumps or to an approved C&D Landfill;
3. Grade surface, cover with soil and re-vegetate; and
4. Achieve intended use.

The Rehabilitation Decision Tool (RDT) provides a methodology for the description and comparison of alternative remediation scenarios relying on the RSI. The RDT is based on a decision tree module.

Two decision trees were thus generated to properly address MSW dumps and CDW dumps (Figure 1 and Figure 2. These were built based on a set of Yes/No questions, the answers to which would lead to one path or another, ultimately revealing the most suitable rehabilitation option.

[3] "Treat" might include sorting, composting, degasification, Waste to Energy (WtE) applications, etc…

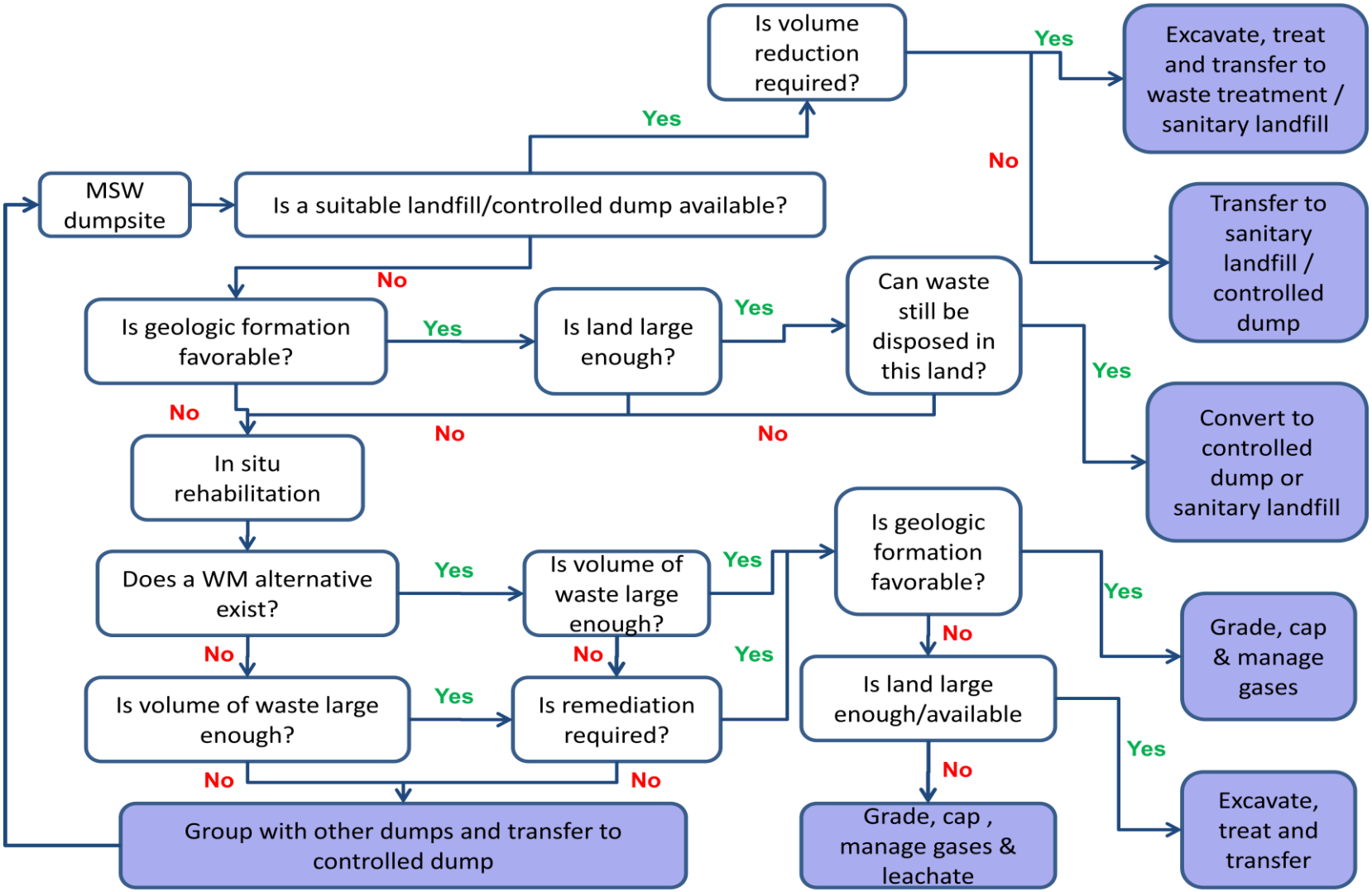


Figure 1 MSW Dumps Rehabilitation Options Decision Tree

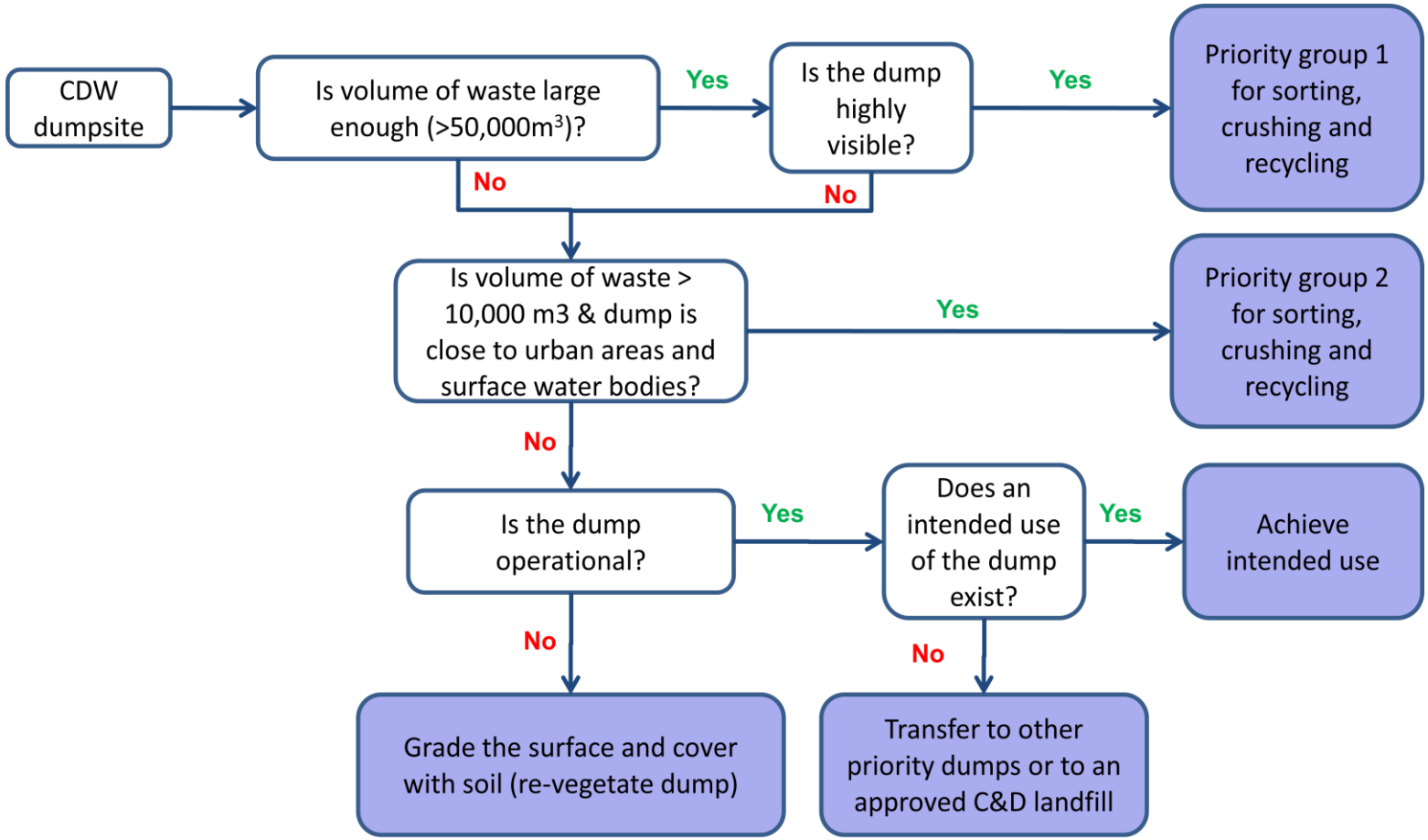


Figure 2 CDW Dumps Rehabilitation Options Decision Tree

The most suitable rehabilitation option was automatically identified for all dumps. Proposed rehabilitation plans for the twenty (20) highest ranked dumps are shown here (Table 6 and Table 7).

Table 6 Proposed Rehabilitation Plan for 20 MSW Priority Dumps

RANK	SITE_ID	RSI	PROPOSED REHABILITATION PLAN
1	G-2-Saida	47.49	Grade, cap, manage gases and leachate
2	C1-Deir Qanoun El - Aain-01	36.97	Grade, cap, manage gases and leachate
3	N5-Hbaline-0	35.12	Grade, cap, manage gases and leachate
4	T9-Srar-0	33.88	Grade, cap, manage gases and leachate
5	R7-Adweh-0	32.64	Grade, cap, manage gases and leachate
6	E4-Kfar Tibnit-00	32.08	Grade, cap, manage gases and leachate
7	J7-Barr Elias-00	31.82	Excavate, treat and transfer
8	P5-Hamat-1	30.54	Grade, cap, manage gases and leachate
9	M9-Baalback-02	28.25	Excavate, treat and transfer to waste treatment/sanitary landfill
10	M9-Baalback-01	27.74	Grade, cap and manage gases
11	J6-Qabb Elias-00	27.05	Grade, cap, manage gases and leachate
12	G2-GhaziyΘ-00	25.98	Grade, cap and manage gases
13	S7-Mqaiteaa-0	25.62	Grade, cap, manage gases and leachate
14	R9-Fnaydek-0	24.40	Grade, cap, manage gases and leachate
15	L8-Haouch el Refqa-00	23.93	Grade, cap, manage gases and leachate
16	L4-Zouk Al Khrab-1	23.65	Grade, cap and manage gases
17	J5-Rouayset El Ballout-0	23.57	Group with other dumps and transfer to controlled dump
18	K7-Timnine-00	23.41	Group with other dumps and transfer to controlled dump
19	R8-Birkayel-0	23.17	Grade, cap, manage gases and leachate
20	P7-Beslouqit-2	22.66	Group with other dumps and transfer to controlled dump

Table 7 Proposed Rehabilitation Plan for 20 CDW Priority Dumps

RANK	SITE_ID	RSI	PROPOSED REHABILITATION PLAN
1	L8-Chmestar-01	27.34	Achieve intended use *(enlarge road)*
2	I4-Ammiq Ech Chouf-0	21.84	Achieve intended use *(transform to a garden/plant trees)*
3	I4-Dmit-0	21.46	Priority Group 1 for Sorting, crushing and recycling
4	K4-Beit Meri-00	21.35	Priority Group 2 for Sorting, crushing and recycling
5	B-3-Kounine-02	21.02	Achieve intended use *(garden or playground)*
6	L4-Mtayleb-1	20.98	Achieve intended use *(building road)*
7	K5-Mar Moussa Ed-Douar-0	20.35	Achieve intended use *(agriculture)*
8	L5-Aain Er-Rihane-3	20.08	Achieve intended use *(road costruction)*
9	L5-Qlaiaat-3	19.88	Priority Group 1 for Sorting, crushing and recycling
10	L4-Zouk Al Khrab-2	19.52	Priority Group 2 for Sorting, crushing and recycling
11	L4-Dik Al-Mahdi-0	19.38	Priority Group 2 for Sorting, crushing and recycling
12	I5-Maaser Ech Chouf-0	19.28	Achieve intended use *(football court and parking)*
13	E-5-Chebaa-01	18.62	Priority Group 1 for Sorting, crushing and recycling
14	L4-Zouk Mousbeh-7	18.55	Achieve intended use
15	I4-Aatrine-1	18.22	Achieve intended use *(annex to football court)*
16	L4-Zouk Al Khrab-4	18.22	Priority Group 2 for Sorting, crushing and recycling
17	L4-Zouk Al Khrab-3	18.21	Transfer to other priority dumps
18	M5-Kfar Yasine-0	18.11	Achieve intended use *(road construction)*
19	J5-Chbaniye-0	18.09	Priority Group 2 for Sorting, crushing and recycling
20	J4-Aaytat-0	17.91	Achieve intended use *(transform to a garden)*

The same interface created for running the Risk Sensitivity Index (RSI) can be used to automatically generate the preferred rehabilitation option and its related costs for all dumps.

The designed model automatically calculates the average cost ($/m3) and the total cost (US $) per dump depending on the rehabilitation type and the volume. These results are displayed in a standalone table (independent of the model) where the dump ID, its coordinates, the Caza and Mohafazat, the RSI score, rehabilitation type, average cost and total cost are displayed.

4. ACTION FICHES

Once the models were run over all dumps, detailed rehabilitation Action Fiches were developed for the twenty -priority dumps (20 highest ranking dumps) of each of the MSW and CDW dumps categories.

The 40 Action Fiches detail the following, along with selected pictures:

1. Site name and location
2. Type of dump
3. Estimated volume of wastes (m^3)
4. Priority ranking for rehabilitation
5. Preferred rehabilitation option
6. Technical requirements (to be used as part of ToRs for contractor)
7. Responsibility
8. Legal requirements, if any
9. Monitoring requirements
10. Operation and maintenance requirements
11. Estimated cost
12. Possible sources of financing

Similar Action Fiches were generated for the remaining dumps (630); presenting the same information detailed above, with 3 variations:

- No pictures
- No technical requirements
- No detailed estimated cost

The designed GIS interface contains an option that displays a printable version of all Action Fiches.

5. COST ESTIMATES SUMMARY

Table 8 summarizes total cost estimates for the rehabilitation of all MSW and CDW dumps.

Table 8 Summary of Total Estimated Costs

MSW DUMPS	**COST ($)**
Estimated cost of rehabilitating first 20 ranked dumps	34,313,942
Estimated cost of rehabilitating 504 MSW dumps	42,288,887
CDW DUMPS	**COST ($)**
Estimated cost of rehabilitating first 20 ranked dumps	5,560,552
Estimated cost of rehabilitating 166 CDW dumps	9,356,988
Total estimated cost of rehabilitating 670 open dumps	**51,645,875**

RÉSUMÉ OPÉRATIONNEL

ELARD a été contracté par le PNUD et le Ministère de l'Environnement afin de préparer un Plan Directeur pour la Réhabilitation et la Fermeture des Décharges Non-contrôlées au Liban. Le Plan Directeur a pour objectif de:

- Etablir une base de données exhaustive des décharges sauvages non-contrôlées au Liban (Déchets Solides Municipaux (DSM) et Déchets de Construction et de Démolition (DCD)[4]) ;
- Ordonner les décharges par ordre de priorité d'intervention; et
- Identifier les méthodes de réhabilitation les mieux adaptées à chaque décharge et développer un plan d'action pour sa réhabilitation et/ou fermeture.

Ce rapport décrit les méthodologies de travail adoptées dans la préparation du Plan Directeur et en résume les principales conclusions.

1. Enquête et Génération d'une Base de Données

Trois équipes d'enquêteurs, composées d'un Géologue et d'un Environnementaliste chacune, ont été mobilisées pour localiser et sonder toutes les décharges sauvages non-contrôlées au Liban. Ces équipes ont procédé par Caza, établissant des contacts avec les municipalités et les Mairies, et organisant des rendez-vous sur terrain avec celles où une décharge aura été identifiée.

Les visites de terrain ont permis de collecter toutes les informations relatives à chaque décharge et de les insérer dans un Formulaire de Caractérisation digitalisé. Les coordonnées géographiques et les surfaces ont aussi été mesurées au GPS, et des photos des décharges et de leur entourage ont été prises. Toutes les données collectées étaient régulièrement transmises aux experts en SIG et en Déchets Solides pour Assurance Qualité / Contrôle Qualité.

Au total, 670[5] décharges ont été identifiées et sondées sur la totalité du territoire Libanais (Tableau 1). Une fois le Formulaire de Caractérisation complété, les informations ont été intégrées dans un Système d'Intégration Géographique (SIG). Le format SIG permet de visualiser et de comparer toutes les informations relatives à toutes les décharges, représentées sur une carte géographique.

[4] Ont été exclus de l'étude:
- La décharge de Tripoli, ayant déjà été réhabilitée
- La décharge de Bourj Hammoud, ayant été fermée depuis 1997, en plus des plans actuels de transformer son site en une Station de Traitement des Eaux Usées pour le Mont-Liban
- Les sites d'enfouissement contrôlés (Naameh, Bsalim, et Baalbeck)

[5] This number is subject to change as MSW and CDW dumps are likely to unexpectedly emerge in new locations after the completion of this project.

Tableau 1 Nombre Total de Décharges Identifiées et Sondées

	NOMBRE	VOLUME (m^3)
Décharges DSM	504	5,004,076
Décharges DCD	166	1,731,180
TOTAL	**670**	**6,735,256**

2. Prioritisation

Un Outil de Décision pour la Prioritisation (ODP) a été développé afin de pouvoir prioritiser les décharges selon un Indice de Sensibilité au Risque (ISR). Deux modèles ont donc été développés pour traiter des décharges de DSM et de DCD séparément, vu que ces deux catégories sont caractérisées par des traits assez différents.

Pour cela, dix (10) attributs ont été sélectionnés pour la prioritisation des décharges de DSM, et huit (8) pour celle des décharges de DCD. Un « poids » a été attribué à chacun de ces attributs, reflétant la gravité relative de l'impact environnemental et social associé à cet attribut. Ces poids sont compris entre 1 et 10 pour les décharges DSM et entre 1 et 8 pour les décharges DCD. Ensuite, chaque attribut a été affecté d'un « grade de sensibilité » entre 0 et 1, divisé sur 4 classes (Table 3-2; Table 3-3).

Tableau 2 Tableau d'Attributs des Décharges DSM

ATTRIBUT		FACTEUR DE PONDERATION	0.0-0.25	0.25-0.5	0.5-0.75	0.75-1.0
Quantité totale de déchets (m3)		10	<10,000 m3	10,000 - 50,000m3	50000 - 100000 m3	>100,000 m3
Géologie	Lithologie (70%)	9	Teneur en Argile considérable a élevée	Contenu en Argile et système de fissures	Porosité secondaire, différentes formes de karstification, et présence de quelques intercalations de Marne	Porosité secondaire (fissures) en roche carbonatée, plus karstification élevée
	Failles et densité des linéaments (segment/km2) (30%)		<10	10-15	15-20	> 20
Hydrologie	Distance aux lignes de drainage (80%)	8	>200m	200-100m	50-75 m	<50m
	Distance aux sources (20%)		>200m	200-150m	150-100 m	<100 m
Distance aux aires urbaines		7	> 1000 m	1000 - 500 m	250 - 500 m	<250 m
Quantité de déchets déchargée par jour (t/j)		6	<10 t/j	10-50 t/j	50 - 100 t/j	>100 t/j
Présence d'alternatives		5	Pas d'alternatives	Solution alternative et financement sous considération	Alternative en cours de construction	Alternative disponible
Brûlage des déchets à ciel ouvert		4	Présent		Non Présent	
Visibilité		3	Not visible		Visible	
Profondeur (m)		2	<1m	1 - 5 m	5-10 m	>10 m
Durée d'exposition (années)		1	< 10 year	10-20 years	20-30 years	>30 years

Tableau 3 Tableau d'Attributs des Décharges DCD

ATTRIBUT		FACTEUR DE PONDERATION	0.0-0.25	0.25-0.5	0.5-0.75	0.75-1.0
Quantité totale de déchets (m3)		8	<10,000 m3	10,000 - 50,000m3	50000 - 100000 m3	>100,000 m3
Visibilité		7	Non Visible		Visible	
Hydrologie	Distance aux lignes de drainage (80%)	6	>200m	200-100m	50-75 m	<50m
	Distance aux sources (20%)		>200m	200-150m	150-100 m	<100 m
Distance aux Aires Urbaines		5	> 1000 m	1000 - 500 m	250 - 500 m	<250 m
Présence d'alternatives/Usage prévu		4	Pas d'alternatives	Solution alternative et financement sous considération	Alternative en cours de construction	Alternative disponible
Statut (Abandonné/Opérationnel)		3	Abandonné		Opérationnel	
Géologie	Lithologie (70%)	2	Teneur en Argile considérable a élevée	Contenu en Argile et système de fissures	Porosité secondaire, différentes formes de karstification, et présence de quelques intercalations de Marne	Porosité secondaire (fissures) en roche carbonatée, plus karstification élevée
	Failles et densité des linéaments (segment/km2) (30%)		<10	10-15	15-20	> 20
Durée d'exposition (années)		1	< 10 year	10-20 years	20-30 years	>30 years

L'indice de Sensibilité au Risque (ISR) a ensuite été calculé selon l'équation suivante:

Equation 2

$$ISR = \sum_{n=1}^{n} W_i S_i$$

Où:

W_i: est le facteur de pondération de la variable i (entre 1 et 10)
S_i: est le grade de sensibilité de la variable i (entre 0 et 1)
ISR: est l'Indice de Sensibilité au Risque (entre 0 et 55 pour les DSM et entre 0 et 36 pour les DCD)

Un score ISR plus élevé indique un risque plus grave pour la santé humaine et pour l'environnement, et évoque par conséquent que la décharge nécessite une intervention plus urgente. Contrairement, lorsque l'ISR diminue, la priorité de réhabilitation diminue aussi.

Une Analyse de Sensibilité a été menée afin de vérifier et de confirmer la validité du modèle. Les résultats ont suggéré que le modèle est très stable. Quoi qu'il en soit, il est à noter que des plans de réhabilitation ont été proposés pour toutes les décharges indépendamment de leur score ISR ; le Plan Directeur en tant que tel n'est donc point affecté par le résultat de l'exercice de prioritisation.

Bien que l'ISR ait été calculé pour la totalité des décharges, uniquement les vingt (20) décharges à l'ISR le plus élevé sont représentées ci-dessous (Table 3-6). Ces 20 décharges prioritaires :

- Représentent 70% et 75% du volume total des décharges de DSM et de DCD (71% du volume total combiné);
- Comprennent toutes les décharges du premier rang de priorité et une part du second rang de priorité (8% et 25% des décharges DSM et DCD);
- Représentent 4% et 12% du nombre total de décharges DSM et DCD (5% en total); et
- Comprennent toutes les décharges a ISR > 40% et >50% du ISR maximal pour les décharges DSM et DCD.

Tableau 4 20 Décharges DSM à l'ISR le plus élevé

RANK	DUMP ID	MOUHAFAZA	CAZA	RSI SCORE
1	G-2-Saida	South	Saida	47.49
2	C1-Deir Qanoun El - Aain-01	South	Sour	36.97
3	N5-Hbaline-0	Mount Lebanon	Jbeil	35.12
4	T9-Srar-0	North	Akkar	33.88
5	R7-Adweh-0	North	Minieh	32.64
6	E4-Kfar Tibnit-00	Nabatieh	Nabatieh	32.08
7	J7-Barr Elias-00	Beqaa	Zahle	31.82
8	P5-Hamat-1	North	Batroun	30.54
9	M9-Baalback-02	Beqaa	Baalback	28.25
10	M9-Baalback-01	Beqaa	Baalback	27.74
11	J6-Qabb Elias-00	Beqaa	Zahle	27.05
12	G2-Ghaziye-00	South	Saida	25.98
13	S7-Mqaiteaa-0	North	Minyeh-donniye	25.62
14	R9-Fnaydek-0	North	Akkar	24.40
15	L8-Haouch el Refqa-00	Beqaa	Baalback	23.93
16	L4-Zouk Al Khrab-1	Mount Lebanon	Maten	23.65
17	J5-Rouayset El Ballout-0	Mount Lebanon	Baabda	23.57
18	K7-Timnine-00	Beqaa	Baalback	23.41
19	R8-Birkayel-0	North	Akkar	23.17
20	P7-Beslouqit-2	North	Zgharta	22.66

Tableau 5 20 Décharges CDC à l'ISR le plus élevé

RANK	DUMP ID	MOUHAFAZA	CAZA	RSI SCORE
1	L8-Chmestar-01	Beqaa	Baalback	27.34
2	I4-Ammiq Ech Chouf-0	Mount Lebanon	Shouf	21.84
3	I4-Dmit-0	Mount Lebanon	Shouf	21.46
4	K4-Beit Meri-00	Mount Lebanon	Metn	21.35
5	B-3-Kounine-02	Nabatieh	Bent Jbeil	21.02
6	L4-Mtayleb-1	Mount Lebanon	Metn	20.98
7	K5-Mar Moussa Ed-Douar-0	Mount Lebanon	Metn	20.35
8	L5-Aain Er-Rihane-3	Mount Lebanon	Kisirween	20.08
9	L5-Qlaiaat-3	Mount Lebanon	Kisirween	19.88
10	L4-Zouk Al Khrab-2	Mount Lebanon	Metn	19.52
11	L4-Dik Al-Mahdi-0	Mount Lebanon	Metn	19.38
12	I5-Maaser Ech Chouf-0	Mount Lebanon	Shouf	19.28
13	E-5-Chebaa-01	Nabatieh	Hasbaya	18.62
14	L4-Zouk Mousbeh-7	Mount Lebanon	Kisirween	18.55
15	I4-Aatrine-1	Mount Lebanon	Shouf	18.22
16	L4-Zouk Al Khrab-4	Mount Lebanon	Metn	18.22
17	L4-Zouk Al Khrab-3	Mount Lebanon	Metn	18.21
18	M5-Kfar Yasine-0	Mount Lebanon	Kisirween	18.11
19	J5-Chbaniye-0	Mount Lebanon	Baabda	18.09
20	J4-Aaytat-0	Mount Lebanon	Aalay	17.91

Une interface SIG a été développée afin de permettre le calcul automatique de l'Indice de Sensibilité au Risque (ISR) pour toutes les décharges de la base de données. L'utilisateur peut même répéter l'exercice en interchangeant les poids donnés aux attributs.

Un code a aussi été développé pour symboliser et classifier les décharges selon leur score ISR. Enfin, un bouton d'aide (« Help ») permet d'afficher des textes visant à guider l'utilisateur à travers l'interface.

3. Réhabilitation

Les mesures de réhabilitation diffèrent d'une décharge à l'autre, selon la complexité du cas et la disponibilité de solutions alternatives.

Sept (7) mesures de réhabilitation ont été considérées pour les décharges SDM, à savoir :

1. Excaver, traiter[6], et transférer les déchets à une installation de traitement[7]/site d'enfouissement sanitaire
2. Transférer à un site d'enfouissement sanitaire/ décharge contrôlée
3. Convertir en une décharge contrôlée ou en site d'enfouissement sanitaire
4. Excaver, Traiter et transférer
5. Niveler, couvrir et gérer les gaz
6. Niveler, couvrir et gérer les gaz et les lixiviats
7. Grouper avec d'autres décharges et transférer à une décharge contrôlée

De plus, quatre (4) mesures de réhabilitation ont été considérées pour les décharges DCD:

1. Séparer, broyer et recycler
2. Transférer à une autre décharge prioritaire ou à un site d'enfouissement de DCD
3. Niveler, couvrir de sol et re-végéter
4. Réaliser l'usage prévu

L'Outil de Décision pour la Réhabilitation (ODR) consiste en une méthodologie pour la description et la comparaison des différentes alternatives et scenarios, selon l'ISR. L'ODR se base sur des Arbres de Décision.

Deux Arbres de Décision ont donc été générés afin de traiter séparément des décharges de SDM et de CDD (Figure 1et Figure 2). Ceux-ci ont été développés à partir d'un nombre de questions, dont les réponses (Oui/Non) mènent à l'un ou l'autre de deux trajets conduisant en fin de compte à l'option de réhabilitation la plus adaptée.

[6] Traiter peut comprendre le fait de séparer, composter, gazéifier, convertir en énergie, etc.

[7] Installation de traitement: peut comprendre les installations de production d'énergie, de compostage, etc.

Figure 1 Arbre de Décision – Décharges DSM

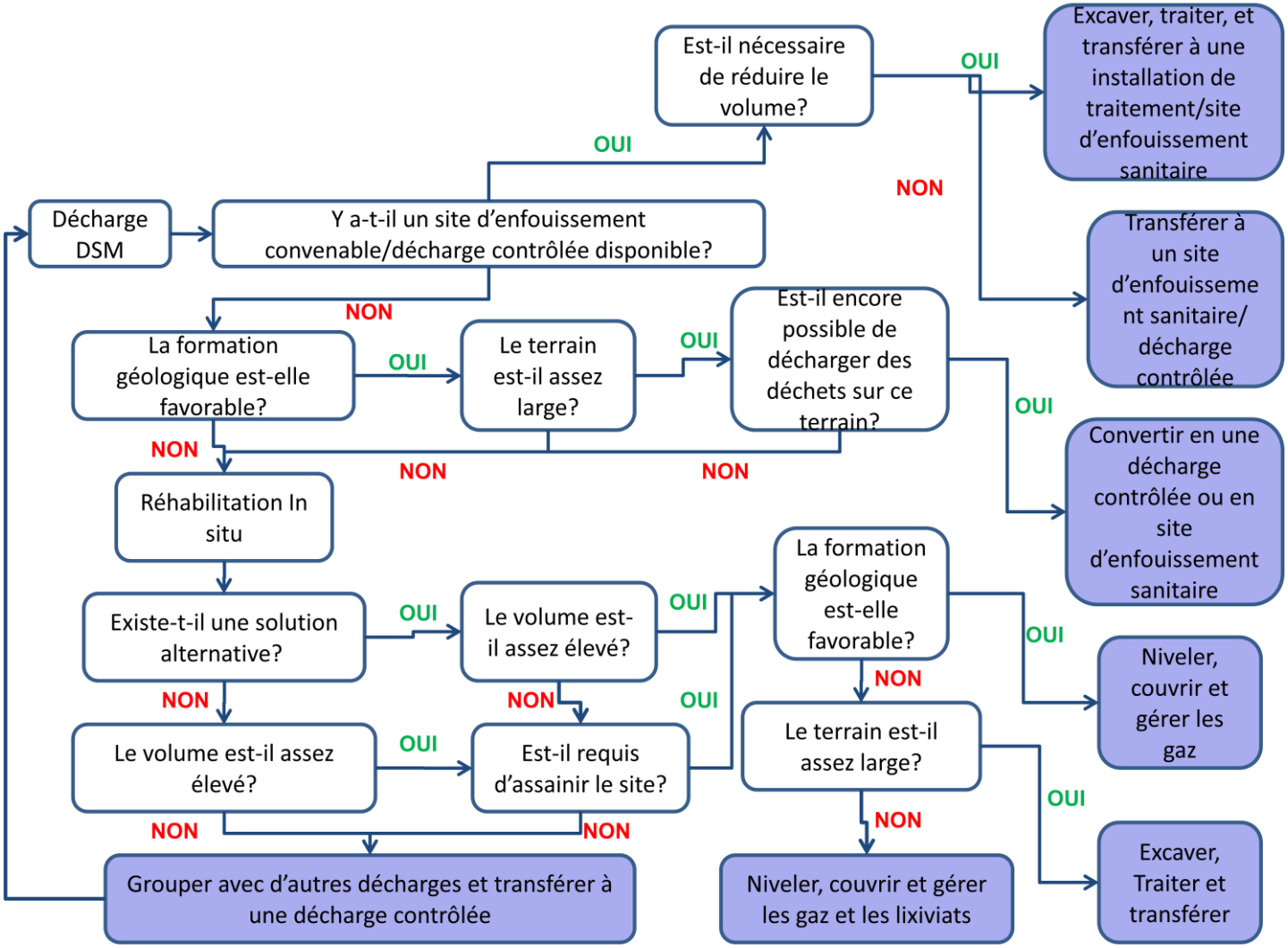
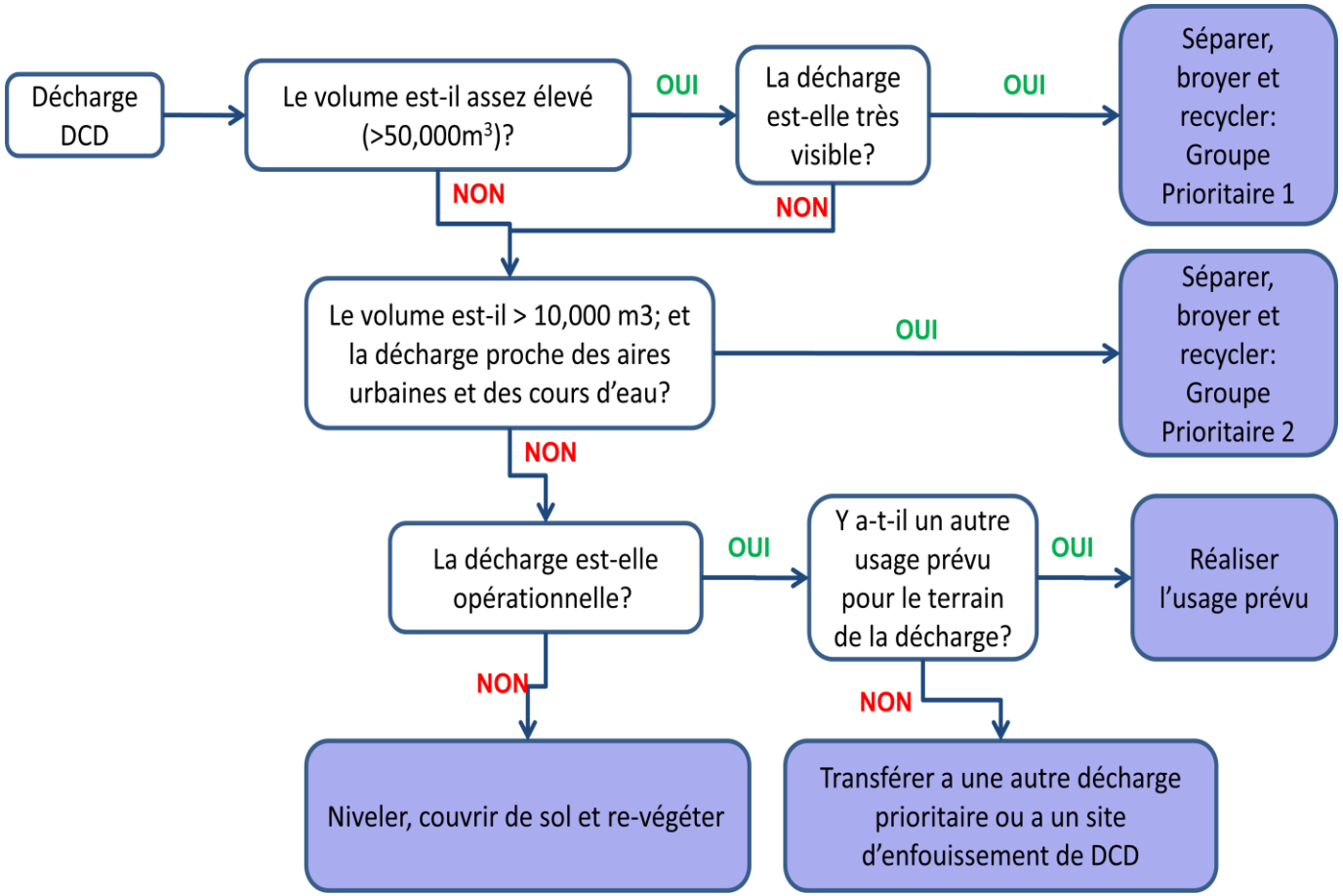


Figure 02 Arbre de Décision – Décharges DCD



L'option de réhabilitation la mieux adaptée a été identifiée pour toutes les décharges de la base de données. Les mesures proposées pour les 20 décharges prioritaires d'entre elles sont présentées ci-dessous.

Tableau 6 Plan de Réhabilitation Proposé pour les 20 Décharges Prioritaires DSM

RANG	DECHARGE	ISR	PLAN DE REHABILITATION PROPOSE
1	G-2-Saida	47.49	Niveler, couvrir et gérer les gaz et les lixiviats
2	C1-Deir Qanoun El - Aain-01	36.97	Niveler, couvrir et gérer les gaz et les lixiviats
3	N5-Hbaline-0	35.12	Niveler, couvrir et gérer les gaz et les lixiviats
4	T9-Srar-0	33.88	Niveler, couvrir et gérer les gaz et les lixiviats
5	R7-Adweh-0	32.64	Niveler, couvrir et gérer les gaz et les lixiviats
6	E4-Kfar Tibnit-00	32.08	Niveler, couvrir et gérer les gaz et les lixiviats
7	J7-Barr Elias-00	31.82	Excaver, Traiter et transférer
8	P5-Hamat-1	30.54	Niveler, couvrir et gérer les gaz et les lixiviats
9	M9-Baalback-02	28.25	Transférer à un site d'enfouissement sans réduire le volume
10	M9-Baalback-01	27.74	Niveler, couvrir et gérer les gaz
11	J6-Qabb Elias-00	27.05	Niveler, couvrir et gérer les gaz et les lixiviats
12	G2-GhaziyΘ-00	25.98	Niveler, couvrir et gérer les gaz
13	S7-Mqaiteaa-0	25.62	Niveler, couvrir et gérer les gaz et les lixiviats
14	R9-Fnaydek-0	24.40	Niveler, couvrir et gérer les gaz et les lixiviats
15	L8-Haouch el Refqa-00	23.93	Niveler, couvrir et gérer les gaz et les lixiviats
16	L4-Zouk Al Khrab-1	23.65	Niveler, couvrir et gérer les gaz
17	J5-Rouayset El Ballout-0	23.57	Grouper avec d'autres décharges et transférer
18	K7-Timnine-00	23.41	Grouper avec d'autres décharges et transférer
19	R8-Birkayel-0	23.17	Niveler, couvrir et gérer les gaz et les lixiviats
20	P7-Beslouqit-2	22.66	Grouper avec d'autres décharges et transférer

Tableau 7 Plan de Réhabilitation Proposé pour les 20 Décharges Prioritaires DCD

RANG	DECHARGE	ISR	PLAN DE REHABILITATION PROPOSE
1	L8-Chmestar-01	27.34	Réaliser l'usage prévu (elargir la route)
2	I4-Ammiq Ech Chouf-0	21.84	Réaliser l'usage prévu (transformer en jardin)
3	I4-Dmit-0	21.46	Séparer, broyer et recycler - Groupe Prioritaire 1
4	K4-Beit Meri-00	21.35	Séparer, broyer et recycler - Groupe Prioritaire 2
5	B-3-Kounine-02	21.02	Réaliser l'usage prévu (jardin ou aire de jeu)
6	L4-Mtayleb-1	20.98	Réaliser l'usage prévu (construction de route)
7	K5-Mar Moussa Ed-Douar-0	20.35	Réaliser l'usage prévu (agriculture)
8	L5-Aain Er-Rihane-3	20.08	Réaliser l'usage prévu (construction de route)
9	L5-Qlaiaat-3	19.88	Séparer, broyer et recycler - Groupe Prioritaire 1
10	L4-Zouk Al Khrab-2	19.52	Priority Group 2 for Sorting, crushing and recycling
11	L4-Dik Al-Mahdi-0	19.38	Priority Group 2 for Sorting, crushing and recycling
12	I5-Maaser Ech Chouf-0	19.28	Réaliser l'usage prévu (terrain de foot et zone de stationnement)
13	E-5-Chebaa-01	18.62	Séparer, broyer et recycler - Groupe Prioritaire 1
14	L4-Zouk Mousbeh-7	18.55	Réaliser l'usage prévu
15	I4-Aatrine-1	18.22	Réaliser l'usage prévu (annexe a un terrain de foot)
16	L4-Zouk Al Khrab-4	18.22	Séparer, broyer et recycler - Groupe Prioritaire 2
17	L4-Zouk Al Khrab-3	18.21	Transfer to other priority dumps
18	M5-Kfar Yasine-0	18.11	Réaliser l'usage prévu (construction de route)
19	J5-Chbaniye-0	18.09	Séparer, broyer et recycler - Groupe Prioritaire 2
20	J4-Aaytat-0	17.91	Réaliser l'usage prévu (transformer en jardin)

La même interface créée pour la génération de l'ISR peut être utilisée pour l'identification automatique de la mesure de réhabilitation la mieux adaptée à chaque décharge, ainsi que l'estimation des coûts associés.

Le modèle sert donc à calculer automatiquement le coût moyen ($/m3) et le coût total ($/m3) pour chaque décharge, selon le type de réhabilitation, le type de décharge, et le volume des déchets. Ces résultats sont ensuite représentés dans un tableau montrant le nom de la décharge, ses coordonnées, la Caza et Mohafazat, son score ISR, le type de réhabilitation proposé, et le cout moyen et total associés a son exécution.

4. Fiches d'Action

Une fois les deux modèles exécutés, des Fiches d'Action détaillées ont été préparées pour les 20 décharges prioritaires de chacune des deux catégories (DSM et DCD). Les 40 Fiches d'Action détaillées listent ce qui suit, en plus de quelques photographies :

1. Le nom et l'emplacement du site
2. Le type de décharge
3. Le volume de déchets estimé (m^3)
4. Le rang de priorité pour la réhabilitation
5. L'option de réhabilitation préférée
6. Les exigences techniques *(à utiliser pour la préparation de TdR pour les entrepreneurs)* *
7. La responsabilité / les parties responsables
8. Les exigences légales
9. Les exigences en matière de suivi
10. Les exigences opérationnelles et de maintenance
11. Les coûts estimés en détail*
12. Les sources de financement possibles
13. Quelques photographies et une carte de repérage*

Des Fiches d'Action similaires ont été générées pour les 630 décharges restantes, comprenant toutes les informations des fiches détaillées sauf:

- Les photographies ;
- Les exigences techniques ;
- Les coûts estimés en détail.

L'interface SIG contient aussi une option permettant de générer une version imprimable de toutes les Fiches d' Action.

5. Résumé des Coûts Estimés

La Table 6-7 résume les coûts estimés pour l'exécution de tous les plans de réhabilitation tels que proposés dans ce Plan Directeur pour toutes les décharges de DSM et de DCD.

Tableau 8 Résumé des Coût Totaux Estimés

DÉCHARGES DSM	**COÛT ($)**
Coût estimé pour la réhabilitation des 20 premières décharges de DSM	34,313,942
Coût estimé pour la réhabilitation des 504 décharges de DSM	42,288,887
DÉCHARGES DCD	**COÛT ($)**
Coût estimé pour la réhabilitation des 20 premières décharges de DCD	5,560,552
Coût estimé pour la réhabilitation des 166 décharges de DCD	9,356,988
Coût total estimé pour la réhabilitation des 670 décharges sauvages	**51,645,875**

ملخص تنفيذي

لقد تعاقدت وزارة البيئة بمشاركة برنامج الأمم المتحدة للتنمية مع شركة الأرض للتنمية المتطورة للموارد لتحضير مخطط توجيهي من أجل إغلاق أو إعادة تأهيل المكبات المفتوحة والعشوائية في لبنان. وتهدف هذه الخطة لتحقيق مايلي:

- بناء قاعدة بيانات للنفايات المنزلية (MSW) ونفايات الردميات الناتجة عن عمليات البناء والهدم (CDW) في لبنان[٨].
- ترتيب المكبات بحسب الأولوية والحاجة لإعادة التأهيل.
- تحديد أفضل طرق التأهيل لكل مكب على حدة وتطوير خطة تحدد النشاطات المطلوبة لإعادة التأهيل و/أو إغلاق المكبات المفتوحة.

التقرير التالي يصف المنهجية والإجراءات المتبعة خلال الدراسة ويلخص النتائج التي تم الحصول عليها.

١. الإحصائيات وإنشاء قاعدة البيانات

تمت الإستعانة بثلاثة فرق إحصائية تألف كل منها من جيولوجي وعالم بيئي، وتم مسح وإحصاء كامل المكبات الموجودة في لبنان، بحيث تم الاتصال بكافة البلديات والقرى من قبل الفرق الإحصائية وترتيب زيارات حقلية لمواقع هذه المكبات.

استحصلت الفرق الاحصائية خلال تلك الزيارات على كافة المعلومات المتعلقة بكل مكب، تمت تجميعها وتخزينها على صورة بيانات رقمية. كما وتمت عملية تخزين الإحداثيات والقياسات باستخدام الـ GPS والتقاط الصور للمكبات ومحيطها باستخدام كاميرات مناسبة. وتم ربط هذه البيانات باستخدام الـ GIS والتحقق من دقتها من قبل خبراء النفايات الصلبة وال GIS.

تم إحصاء ٦٧٠ مكب[٩] على امتداد لبنان كما هو موضح في الجدول ١. وبالاستعانة بالـ GIS أمكن تحويل البيانات إلى صيغة تمكننا من مقارنة المعلومات والصور لكافة المكبات.

الجدول ١ العدد الإجمالي وحجم المكبات في لبنان

	العدد	الحجم (m^3)
مكبات MSW	504	5,004,076
مكبات CDW	166	1,731,180
الإجمالي	**670**	**6,735,256**

٢. الأولويات

تم تطوير معيار تحديد الأولوية(PDT) بالاعتماد على مؤشر حساسية الخطر(RSI) بشكل يتيح التعامل مع نوعي المكبات (MSW وCDW) كل على حدى. ولتحقيق هذه الغاية تم اعتماد عشرة خصائص مميزة لمكبات الـ MSW و ثمان خصائص لمكبات الـ CDW ولكل خاصية تأثير مميز عن باقي الخصائص مما يمكننا من تحديد الأثر البيئي لها وبدقة.

[٨] لم تدخل في الإحصائيات:
- مكب طرابلس: تمت إعادة تأهيله مسبقاً.
- مكب برج حمود: المغلث منذ سنة ١٩٩٧، مع الأخذ بعين الاعتبار أنه من المقرر تحويله إلى محطة معالجة مياه الصرف الصحي لجبل لبنان.
- مكبات النفايات المدروسة (مكبات النعمة، بساليم، زحلة وبعلبك).

[٩] هذا الرقم قابل للتغيير وفقاً لتغيرات مكبات الـ MSW و CDW حيث من الممكن أن تدمج وتنقل إلى مواقع جديدة بعد نهاية هذا المشروع.

يتراوح العامل الوزني لكل من هذه الخصائص بين (10→1) لمكبات الـ MSW وبين(8→1) لمكبات الـ CDW، وتعطى حينها كل من هذه الخصائص درجة حساسية تتراوح بين (10→0) وتقسم إلى أربعة مناطق رئيسية كما هو موضح في الجدول ٢ والجدول ٣.

الجدول ٢ خصائص مكبات الـ MSW

ATTRIBUTE		WEIGHING FACTOR	0.0-0.25	0.25-0.5	0.5-0.75	0.75-1.0
Total quantity of waste at site (m3)		10	<10,000 m3	10,000 - 50,000m3	50000 - 100000 m3	>100,000 m3
Geology	Lithology (70%)	9	Considerable to high clay content	Clay contents and jointing systems	Secondary porosity, different forms of karstification and presence of some marl intercalations	Secondary porosity (cracks & joints) of carbonate rock, plus high karstification
	Faults & lineaments density (segment/km2) (30%)		<10	10-15	15-20	> 20
Hydrology	Distance to drainage line (80%)	8	>200m	200-100m	50-75 m	<50m
	Distance to springs (20%)		>200m	200-150m	150-100 m	<100 m
Distance to urban areas		7	> 1000 m	1000 - 500 m	250 - 500 m	<250 m
Quantity of waste currently dumped at site (t/d)		6	<10 t/d	10-50 t/d	50 - 100 t/d	>100 t/d
Presence of alternatives		5	No Alternatives	Working on alternative solution & funding	Alternative under construction	Alternative operational
Open burning of waste		4	Burned		Not Burned	
Visibility		3	Not visible		Visible	
Depth of filling of waste (m)		2	<1m	1 - 5 m	5-10 m	>10 m
Duration of dump exposure (years)		1	< 10 year	10-20 years	20-30 years	>30 years

الجدول ٣ خصائص مكبات الـ CDW

ATTRIBUTE		WEIGHTING FACTOR	0.0-0.25	0.25-0.5	0.5-0.75	0.75-1.0
Volume of waste at site (m3)		8	<10,000 m3	10,000 - 50,000m3	50000 - 100000 m3	>100,000 m3
Visibility		7	Not visible		Visible	
Hydrology	Distance to drainage line (80%)	6	>200m	200-100m	50-75 m	<50m
	Distance to springs (20%)		>200m	200-150m	150-100 m	<100 m
Distance to urban areas		5	> 1000 m	1000 - 500 m	250 - 500 m	<250 m
Presence of alternatives/intended use		4	No alternatives/no plans	Working on alternative solution & funding	Alternative under construction	Alternative operational
Status (Abandoned/Operational)		3	Abandoned		Operational	
Geology	Lithology (70%)	2	Considerable to high clay content	Clay contents and jointing systems	Secondary porosity, different forms of karstification and presence of some marl intercalations	Secondary porosity (cracks & joints) of carbonate rock, plus high karstification
	Faults & lineaments density (segment/km2) (30%)		<10	10-15	15-20	> 20
Duration of dump exposure (yrs)		1	< 10 year	10-20 years	20-30 years	>30 years

تم حساب مؤشر حساسية الخطر(RSI) بعد جمع كافة الخصائص وذلك بعد إجراء عملية الضرب لدرجة الحساسية بالوزن حسب المعادلة 1 .

المعادلة 1

$$RSI = \sum_{n=1}^{n} W_i S_i$$

حيث:

Wi: وزن i^{th} ويتغير من ١ - ١٠

Si: الدخل الحساس لـ i^{th} و يتغير من ٠-١

RSI: مؤشر حساسية الخطر ويتغير من (٠-٥٥) من أجل MSW ومن (٠-٣٦) من أجل CDW.

وبارتفاع هذه القيمة يرتفع معدل الخطورة بالنسبة للإنسان والبيئة والعكس صحيح.

تم إجراء تحليل الحساسية على موديول الـ (PDT) لتأكيد صلاحيته. ولقد أثبت هذا الموديول استقراره في حالة النتيجة.

ومن الجدير بالملاحظة أنه تم اقتراح عملية تأهيل لكل المكبات التي تم إجراء الإحصائيات عليها بغض النظر عن ترتيب الأولوية لها، وبذلك تحافظ الخطة الأساسية على نتائجها بدون أن تتأثر بعامل الأولوية.

على الرغم من حساب مؤشر حساسية الخطر لكل المكبات، سنورد أدناه أعلى ٢٠ قيمة فقط، وهي:

- تمثل حوالي ٧٠% و ٧٥% من الحجم الكلي للمكبات MSW وCDW بالترتيب (بالنسبة للنوعين معاً فإن ٤٠ من المكبات ذات الأولوية العليا تمثل حوالي ٧١% من الحجم الكلي).
- تغطي كل المكبات الواقعة في الجزء الأول من سلم الأولوية وقسم من الجزء الثاني (حوالي ٨% من مكبات الـ MSW و ٢٥% من الـ CDW).
- تمثل بالترتيب ٤% و ١٢% من العدد الإجمالي لمكبات الـ MSW والـ CDW (حوالي ٥% بالمجمل).
- تتمثل بمؤشر حساسية الخطر (RSI) يتعدى ٤٠% و٥٠% من القيمة العظمى لمؤشر حساسية الخطر (RSI).

الجدول ٤ نتائج الـ RSI: أعلى عشرين قيمة لمكبات الـ MSW

الترتيب	DUMP ID	MOUHAFAZA	CAZA	RSI SCORE
1	G-2-Saida	South	Saida	47.49
2	C1-Deir Qanoun El - Aain-01	South	Sour	36.97
3	N5-Hbaline-0	Mount Lebanon	Jbeil	35.12
4	T9-Srar-0	North	Akkar	33.88
5	R7-Adweh-0	North	Minieh	32.64
6	E4-Kfar Tibnit-00	Nabatieh	Nabatieh	32.08
7	J7-Barr Elias-00	Beqaa	Zahle	31.82
8	P5-Hamat-1	North	Batroun	30.54
9	M9-Baalback-02	Beqaa	Baalback	28.25
10	M9-Baalback-01	Beqaa	Baalback	27.74
11	J6-Qabb Elias-00	Beqaa	Zahle	27.05
12	G2-Ghaziye-00	South	Saida	25.98
13	S7-Mqaiteaa-0	North	Minyeh-donniye	25.62
14	R9-Fnaydek-0	North	Akkar	24.40
15	L8-Haouch el Refqa-00	Beqaa	Baalback	23.93
16	L4-Zouk Al Khrab-1	Mount Lebanon	Maten	23.65
17	J5-Rouayset El Ballout-0	Mount Lebanon	Baabda	23.57
18	K7-Timnine-00	Beqaa	Baalback	23.41
19	R8-Birkayel-0	North	Akkar	23.17
20	P7-Beslouqit-2	North	Zgharta	22.66

الجدول ٥ نتائج الـ RSI: أعلى عشرين قيمة لمكبات الـ CDW

الترتيب	DUMP ID	MOUHAFAZA	CAZA	RSI SCORE
1	L8-Chmestar-01	Beqaa	Baalback	27.34
2	I4-Ammiq Ech Chouf-0	Mount Lebanon	Shouf	21.84
3	I4-Dmit-0	Mount Lebanon	Shouf	21.46
4	K4-Beit Meri-00	Mount Lebanon	Metn	21.35
5	B-3-Kounine-02	Nabatieh	Bent Jbeil	21.02
6	L4-Mtayleb-1	Mount Lebanon	Metn	20.98
7	K5-Mar Moussa Ed-Douar-0	Mount Lebanon	Metn	20.35
8	L5-Aain Er-Rihane-3	Mount Lebanon	Kisirween	20.08
9	L5-Qlaiaat-3	Mount Lebanon	Kisirween	19.88
10	L4-Zouk Al Khrab-2	Mount Lebanon	Metn	19.52
11	L4-Dik Al-Mahdi-0	Mount Lebanon	Metn	19.38
12	I5-Maaser Ech Chouf-0	Mount Lebanon	Shouf	19.28
13	E-5-Chebaa-01	Nabatieh	Hasbaya	18.62
14	L4-Zouk Mousbeh-7	Mount Lebanon	Kisirween	18.55
15	I4-Aatrine-1	Mount Lebanon	Shouf	18.22
16	L4-Zouk Al Khrab-4	Mount Lebanon	Metn	18.22
17	L4-Zouk Al Khrab-3	Mount Lebanon	Metn	18.21
18	M5-Kfar Yasine-0	Mount Lebanon	Kisirween	18.11
19	J5-Chbaniye-0	Mount Lebanon	Baabda	18.09
20	J4-Aaytat-0	Mount Lebanon	Aalay	17.91

تم إعداد واجهة GIS للتعامل مع مؤشر حساسية الخطر (RSI) لكلا النوعين من المكبات حيث تم إعطاء الخيار للمستخدم للتغيير بين عوامل الوزن لكلا النوعين ولكل بارامتر. كما تم تطوير مجموعة من الرموز لتمكننا من ترميز وتصنيف المكبات تبعاً لمؤشر حساسية الخطورة. وتم تزويده بزر لعرض تعليمات المساعدة الفورية.

٣. إعادة التأهيل

تختلف الإجراءات الإصلاحية من مكب إلى آخر تبعاً لمدى تعقيد الوضع ومدى توافر البدائل الصالحة. بالنسبة لمكبات الـ MSW يوجد سبعة بدائل هي:

١. الحفر، المعالجة ونقل النفايات إلى منشآت المعالجة/ الترميد أو المطامر.

٢. النقل إلى منشآت الترميد والمطامر/ المكبات المدروسة.

٣. التحويل إلى مكبات مدروسة/ مطامر أو منشآت ترميد.

٤. الحفر، المعالجة[١٠] والنقل.

٥. تسوية الأرض و طمرها والتعامل مع الغازات.

٦. تسوية الأرض و طمرها والتعامل مع الغازات والسوائل الناتجة.

٧. التجميع مع النفايات الناتجة من المكبات الأخرى ثم ترحيلها إلى مكبات مدروسة.

بينما بالنسبة لمكبات الـ CDW يوجد أربعة إجراءات إصلاحية وهي:

١. الفرز، التحطيم وإعادة التدوير.

٢. النقل إلى مكبات C&D موافق عليها.

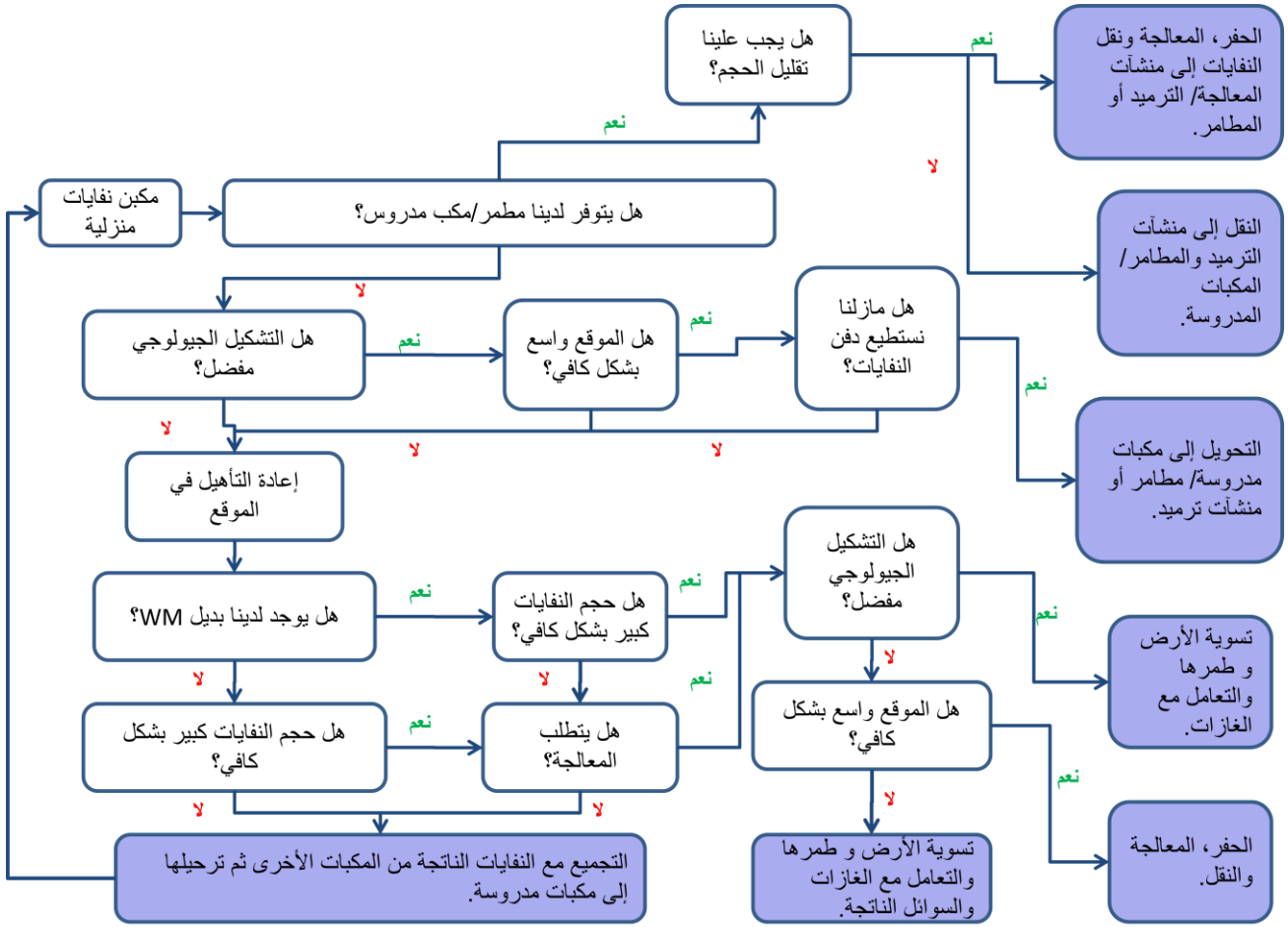
٣. تسوية الأرض و تغطيتها بالتربة وإعادة الغطاء النباتي إليها.

٤. تحقيق الغرض المطلوب منها.

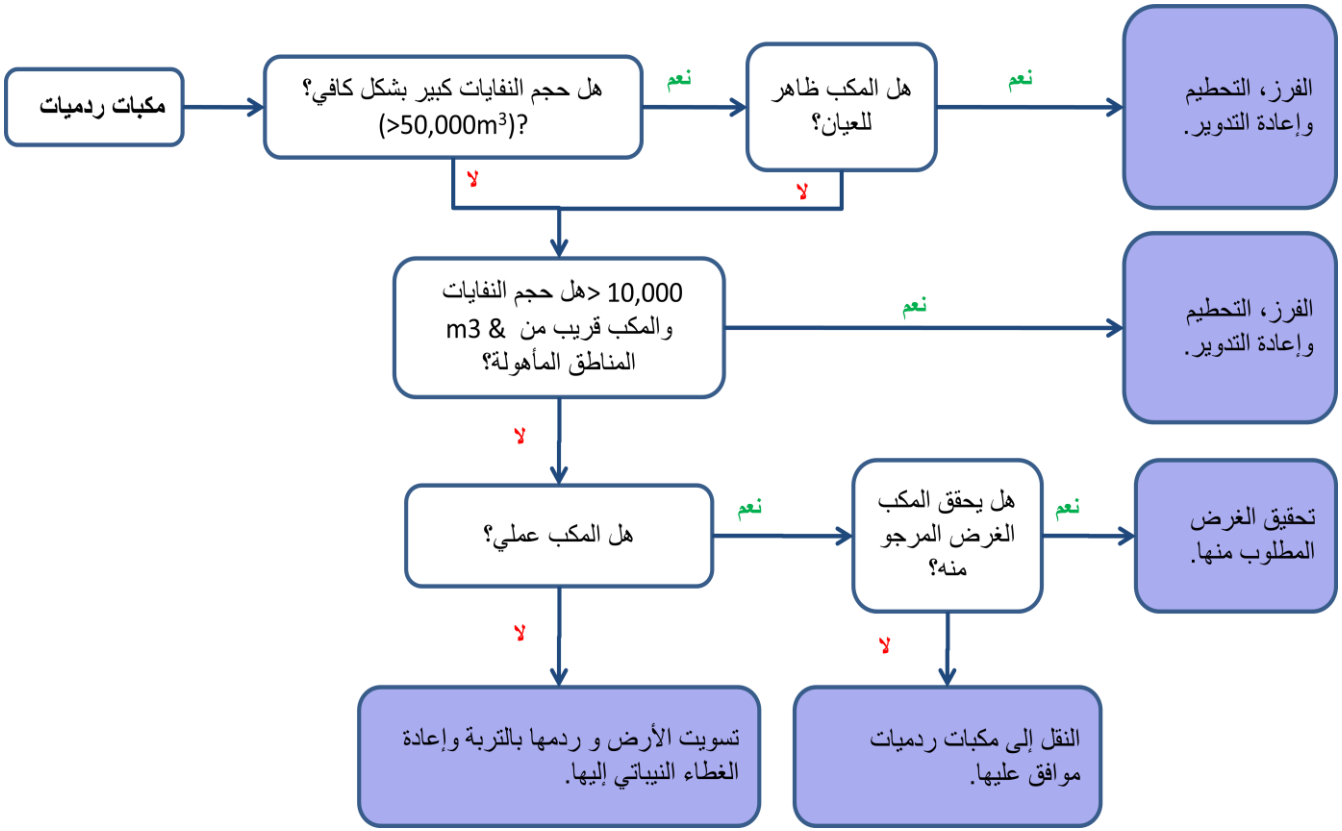
تحدد أدوات قرار إعادة التأهيل (RDT) الطريقة الأنسب لتوصيف ومقارنة الإجراءات الإصلاحية البديلة بالاعتماد على مؤشر حساسية الخطر (RSI). وهي تعتمد على موديول شجرة القرار.

يوجد لدينا نموذجان لشجرة القرار حسب نوع المكب كما هو موضح في الشكل1 والشكل ٢. وتم تشكيلها بالاعتماد على مبدأ سؤال نعم أو لا، مما يؤدي بالمحصلة للوصول إلى أكثر طرق إعادة التأهيل توافقاً مع الحالة المدروسة.

[١٠] المعالجة: قد تتضمن الفرز، الفرز التصنيفي، المعالجات الكيميائية، تطبيقات تحويل النفايات إلى طاقة ...



الشكل 1 شجرة القرار- مكبات MSW



الشكل ٢ شجرة القرار- مكبات CDW

تم تحديد أكثر خيارات إعادة التأهيل توافقاً مع الحالة المدروسة بشكل أوتوماتيكي لكل المكبات المدروسة، وبالنسبة للمكبات العشرين الأولى نجدها في الجدول 6 والجدول7 .

الجدول 6 خطط إعادة التأهيل المقترحة لمكبات الـ MSW العشرين الأولى

الترتيب	SITE_ID	RSI	خطط إعادة التأهيل المقترحة
1	G-2-Saida	47.49	Grade, cap, manage gases and leachate
2	C1-Deir Qanoun El - Aain-01	36.97	Grade, cap, manage gases and leachate
3	N5-Hbaline-0	35.12	Grade, cap, manage gases and leachate
4	T9-Srar-0	33.88	Grade, cap, manage gases and leachate
5	R7-Adweh-0	32.64	Grade, cap, manage gases and leachate
6	E4-Kfar Tibnit-00	32.08	Grade, cap, manage gases and leachate
7	J7-Barr Elias-00	31.82	Excavate, treat and transfer
8	P5-Hamat-1	30.54	Grade, cap, manage gases and leachate
9	M9-Baalback-02	28.25	Excavate, treat and transfer to waste treatment/sanitary landfill
10	M9-Baalback-01	27.74	Grade, cap and manage gases
11	J6-Qabb Elias-00	27.05	Grade, cap, manage gases and leachate
12	G2-GhaziƟ-00	25.98	Grade, cap and manage gases
13	S7-Mqaiteaa-0	25.62	Grade, cap, manage gases and leachate
14	R9-Fnaydek-0	24.40	Grade, cap, manage gases and leachate
15	L8-Haouch el Refqa-00	23.93	Grade, cap, manage gases and leachate
16	L4-Zouk Al Khrab-1	23.65	Grade, cap and manage gases
17	J5-Rouayset El Ballout-0	23.57	Group with other dumps and transfer to controlled dump
18	K7-Timnine-00	23.41	Group with other dumps and transfer to controlled dump
19	R8-Birkayel-0	23.17	Grade, cap, manage gases and leachate
20	P7-Beslouqit-2	22.66	Group with other dumps and transfer to controlled dump

الجدول 7 خطط إعادة التأهيل المقترحة لمكبات الـ CDW العشرين الأولى

الترتيب	SITE_ID	RSI	خطط إعادة التأهيل المقترحة
1	L8-Chmestar-01	27.34	Achieve intended use *(enlarge road*)
2	I4-Ammiq Ech Chouf-0	21.84	Achieve intended use *(transform to a garden/plant trees)*
3	I4-Dmit-0	21.46	Priority Group 1 for Sorting, crushing and recycling
4	K4-Beit Meri-00	21.35	Priority Group 2 for Sorting, crushing and recycling
5	B-3-Kounine-02	21.02	Achieve intended use *(garden or playground)*
6	L4-Mtayleb-1	20.98	Achieve intended use *(building road)*
7	K5-Mar Moussa Ed-Douar-0	20.35	Achieve intended use *(agriculture)*
8	L5-Aain Er-Rihane-3	20.08	Achieve intended use *(road costruction)*
9	L5-Qlaiaat-3	19.88	Priority Group 1 for Sorting, crushing and recycling
10	L4-Zouk Al Khrab-2	19.52	Priority Group 2 for Sorting, crushing and recycling
11	L4-Dik Al-Mahdi-0	19.38	Priority Group 2 for Sorting, crushing and recycling
12	I5-Maaser Ech Chouf-0	19.28	Achieve intended use *(football court and parking)*
13	E-5-Chebaa-01	18.62	Priority Group 1 for Sorting, crushing and recycling
14	L4-Zouk Mousbeh-7	18.55	Achieve intended use
15	I4-Aatrine-1	18.22	Achieve intended use *(annex to football court)*
16	L4-Zouk Al Khrab-4	18.22	Priority Group 2 for Sorting, crushing and recycling
17	L4-Zouk Al Khrab-3	18.21	Transfer to other priority dumps
18	M5-Kfar Yasine-0	18.11	Achieve intended use *(road construction)*
19	J5-Chbaniye-0	18.09	Priority Group 2 for Sorting, crushing and recycling
20	J4-Aaytat-0	17.91	Achieve intended use *(transform to a garden)*

يمكن استخدام نفس الواجهة المستخدمة في حالة مؤشر حساسية الخطر للتعامل مع خيارات إعادة التأهيل والتكاليف المحتملة لكافة المكبات، حيث يتم حساب التكاليف بشكل وسطي ($/m3) والتكلفة النهائية بالـ ($ US) للمكب تبعاً لحجم المكب ونوع إعادة التأهيل المطبق. و سيتم عرض النتائج بشكل تفصيلي بجدول نهائي واضح.

٤. ملخص البيانات:

تم إعداد **ملخص بيانات** لكل المكبات بمجرد الانتهاء من دراستها، حيث احتوى على ما يلي مدعماً بالصور التوضيحية:

١. اسم الموقع ومكانه على الخارطة.
٢. نوع المكب.
٣. الحجم التقديري للنفايات (m^3) .
٤. ترتيب الأولويات من أجل إعادة التأهيل.
٥. خيار إعادة التأهيل الأفضل.
٦. المتطلبات التقنية من أجل إعداد دفاتر الشروط للمتعهدين.
٧. المسؤولية.
٨. المتطلبات القانونية في حال وجودها.
٩. متطلبات المراقبة.
١٠. متطلبات التشغيل والصيانة.
١١. الكلفة التقديرية.
١٢. المصادر المحتملة للتمويل.

بالمثل تم اتخاذ إجراءات مماثلة للمكبات المتبقية (٣٦٠ مكباً)، احتوت على نفس المعلومات المذكورة أعلاه مع ثلاثة فروقات أساسية:

- لا يوجد صور.
- لا يوجد متطلبات تقنية.
- لا يوجد كلفة تقديرية تفصيلية.

تحتوي واجهة الـ GIS على خيار يمكننا من طباعة النشاطات المقترحة.ملخص الكلفة التقديرية.

٥. ملخص الكلفة التقديرية

يوضح الجدول 8 الكلفة التقديرية المتوقعة لإعادة تأهيل جميع مكبات الـ MSW والـ CDW.

الجدول 8 ملخص الكلفة التقديرية

الكلفة ($)	مكبات MSW
34,313,942	الكلفة التقديرية لإعادة تأهيل أول ٢٠ مكباً
42,288,887	الكلفة التقديرية لإعادة تأهيل ٥٠٤ مكب MSW
الكلفة ($)	**مكبات CDW**
5,560,552	الكلفة التقديرية لإعادة تأهيل أول ٢٠ مكباً
9,356,988	الكلفة التقديرية لإعادة تأهيل ١٦٦ مكب CDW
51,645,875	**الكلفة التقديرية لإعادة تأهيل ٦٧٠مكباً مفتوحاً**

1. INTRODUCTION

ELARD has been contracted by the UNDP/MoE to prepare a Master Plan for the Closure and Rehabilitation of Open and Uncontrolled Dumps throughout Lebanon. For this purpose, a six-phase work plan has been proposed and agreed upon, consisting of:

- Phase 1: Inception;
- Phase 2: Survey Preparation;
- Phase 3: Survey Implementation;
- Phase 4: Analysis, Prioritization and Rehabilitation Options;
- Phase 5: Generation of a Draft Master Plan; and
- Phase 6: Generation of a Final Master Plan and Final Presentation

After having completed the first five phases and submitted their corresponding deliverables as per the contract (respectively the Inception Report, First Progress Report, Second Progress Report, and Third Progress Report), the present report recapitulates and builds upon all information and findings from previous reports to introduce the actual Master Plan for the Closure and Rehabilitation of Uncontrolled Dumps in Lebanon.

The report is structured into five (5) main sections in addition to this introduction, as follows:

- ✓ Section 2: Survey and Database Generation
- ✓ Section 3: Prioritization
- ✓ Section 4: Rehabilitation
- ✓ Section 5: Action Fiches

The report also contains six (6) appendices consisting of:

- ✓ GIS Project *(soft copy)*;
- ✓ Prioritization and Rehabilitation Results in Excel Format *(soft copy)*;
- ✓ Action Fiches;
- ✓ High Resolution Maps;
- ✓ Mobile Crusher Budget Requirements; and
- ✓ Presentations.

2. SURVEY AND DATABASE GENERATION

2.1. METHODOLOGY

Three teams of surveyors, each composed of a Geologist and an Environmental Scientist, were mobilized to locate and survey all open and uncontrolled dumps in Lebanon. Each team was assigned an operational area as shown in Figure 2-1.

The survey teams operated under the supervision of a Field Team Leader, while an Office Support Team provided logistical backup and coordinated the communication between the Teams and the Solid Waste and GIS Experts. Introductory and field training sessions were organized prior to the commencement of the Survey.

Field equipment was provided to enable teams to conduct the survey in a practical and safe manner. Additionally, a set of maps were prepared to facilitate the process of screening municipalities and villages and locating dump sites.

A Survey Characterization Form was developed based on the parameters given in the initial technical proposal. The form was designed in excel format and was structured so that data could be entered on the field and later easily imported into a GIS database.

The Survey Implementation was organized as follows:

- ✓ Based on the provided maps, teams proceeded by Caza, screening all municipalities and villages for possible dumps, in addition to those dumps already identified as part of the Inception Phase.
- ✓ Teams and/or Office Support established contact with the municipalities and identified those where Municipal Solid Waste (MSW)[11] or Construction and Demolition Waste (CDW)[12] dumps existed. In the absence of a Municipality, contact was established with the Mayor ("Mokhtar").
- ✓ A meeting was then organized with the most knowledgeable contact person from the Municipality for a field visit to the dump site and an interview.
- ✓ Weekly planning was coordinated between the teams and their field team leader. Field visits were planned in a way so as to optimize the survey procedure, as visits to dumps in one particular area were scheduled on the same day.
- ✓ During the Field Visits, teams:
    2. Determined the exact coordinates of the dump location using a GPS. Whenever possible, several GPS points were taken from around the dump in order to determine the exact dump surface area;

[11] Were considered as Municipal Solid Waste dumps all dumps containing over 85% of Municipal Solid Waste. These might include in addition to MSW: Hospital Waste, Demolition and Construction Waste, Industrial Waste, etc…
[12] Were considered as Construction and Demolition Waste dumps all dumps containing over 85% of Construction and Demolition Waste. These include: rubble, green waste, construction and demolition debris, etc…

3. Took photographs of the dumpsite and its surroundings[13];
4. Collected all information related to the dump as per the characterization form. Any information that was unavailable on the spot was later retrieved from the municipality over the phone;
5. Entered the collected data into the Microsoft Excel Characterization Form using the provided Notebooks.

- ✓ Each surveyed dump was given a specific "Dump ID". These were developed based on the following structure: "Map code"-"Name of village/municipality"-"Dump number"; where:
  - The "Map code" refers to the coding in the General Index Map of Lebanon (Appendix B) for the given dump location;
  - The "Name of village/municipality" reflects the name of the village or municipality using and/or operating the dump, regardless of where the dump actually lies; and
  - The "Dump number" reflects the number of dumps found and surveyed per village/municipality, starting with "00" for the first dump.

  Example: L5-Ballouneh-00; L5-Ballouneh-01; N5-Hbaline-01, etc.
- ✓ Surveyed dumps and areas were reported to the Field Team Leader and Office Support by sending the updated characterization form on a weekly basis via email.
- ✓ All collected data was regularly communicated to both the GIS and the Solid Waste Experts for QA/QC. The GIS expert directly located surveyed dumps and identified any errors in the coordinates. These were reviewed by the teams and corrected using Google Earth when necessary. Geological data was also compared to available geological maps and reviewed whenever discrepancy was observed. The Solid Waste Expert, on the other hand, conducted QA/QC based on the pictures provided for each dump as well as previous knowledge and experience.

[13] It is to be noted that four (4) dumps (E3-Zibdine En Nabatiyeh-02, D2-Maaroub-03, K5-ED Douar-00, and D2-Derdaghaiya-02) were not photographed, as:

- E3-Zibdine En Nabatiyeh-02, D2-Maaroub-03, and K5-ED Douar-00 were unreachable due to critical road conditions. These were identified and located using Google Earth for exact coordinate measurement.
- D2-Derdaghaiya-02 was not operational yet on the date of the visit. It was however surveyed and included in the database as it was projected to start operating by the end of December 2010.

2.2. RESULTS

A total number of 670[14] dumps were identified and surveyed over the Lebanese Territory[15] (Table 2-1). These are shown in Figure 2-1, Figure 2-2 and Figure 2-3 below.

Table 2-1 Total Number and Volume of Dumps Identified

	NUMBER	VOLUME (m^3)
MSW Dumps	504	5,004,076
CDW Dumps	166	1,731,180
TOTAL	**670**	**6,735,256**

[14] This number is subject to change as MSW and CDW dumps are likely to unexpectedly emerge in new locations after the completion of this project.

[15] Were excluded from the survey:

- The Tripoli dump, which has already been rehabilitated;
- The Bourj Hammoud dump, which has been closed since 1997. Additionally, there are plans for turning it into a Wastewater Treatment Plant for Mount Lebanon;
- Controlled waste disposal facilities (the Naameh, Bsalim, Zahle, and Baalback landfills).

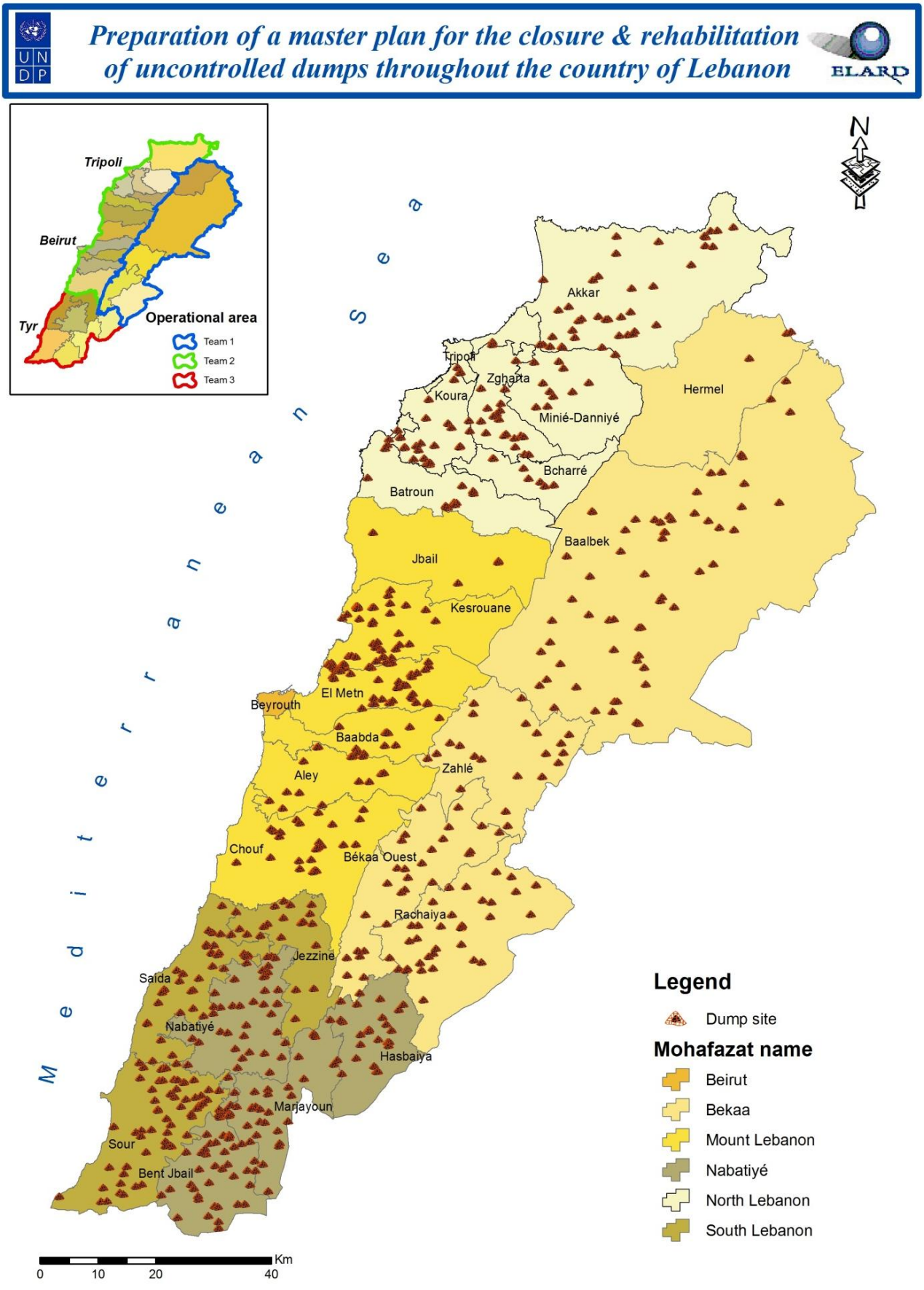


Figure 2-1 Location of Uncontrolled Dumps over the Lebanese Territory

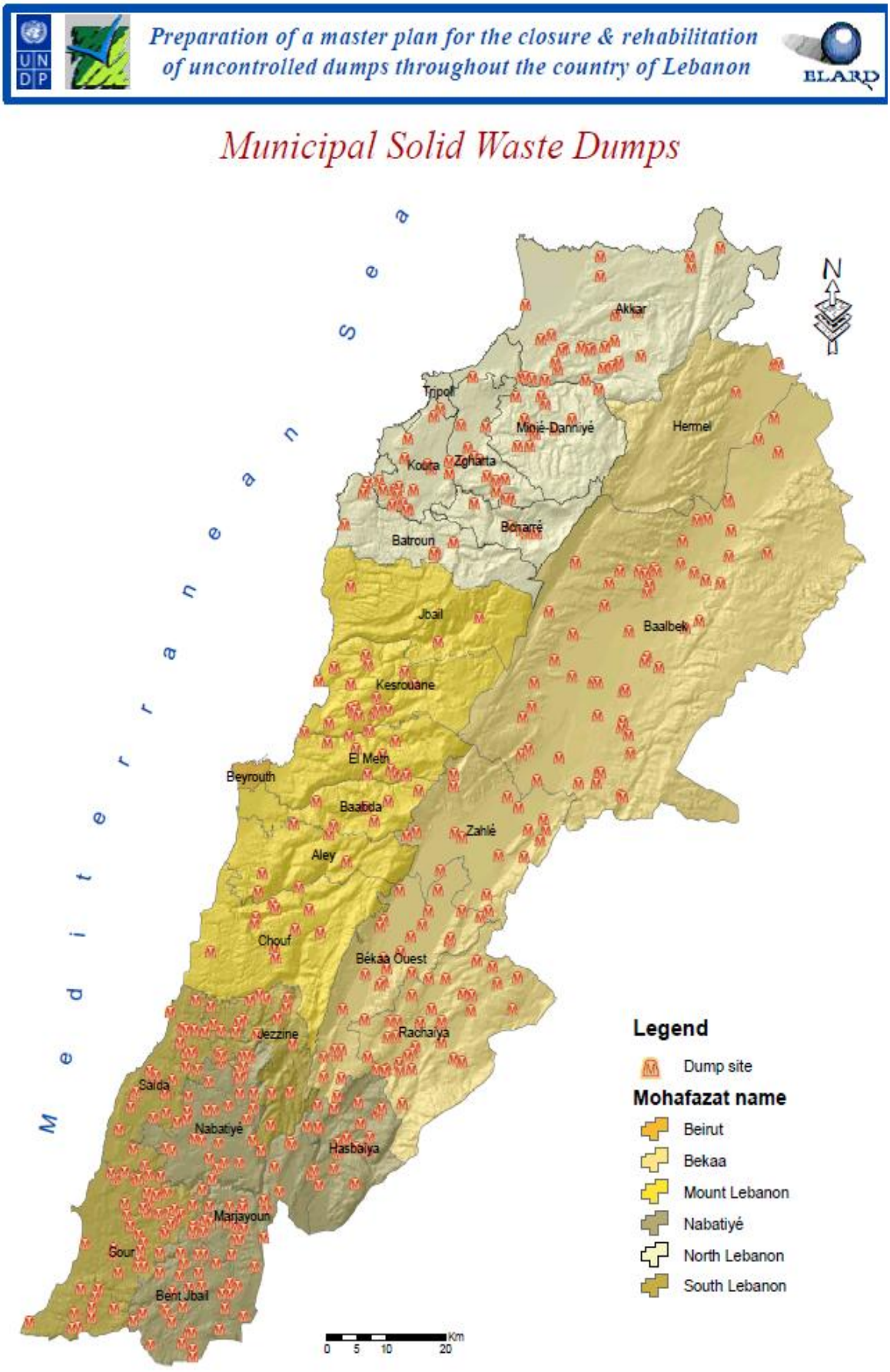


Figure 2-2 Location of MSW Dumps over the Lebanese Territory

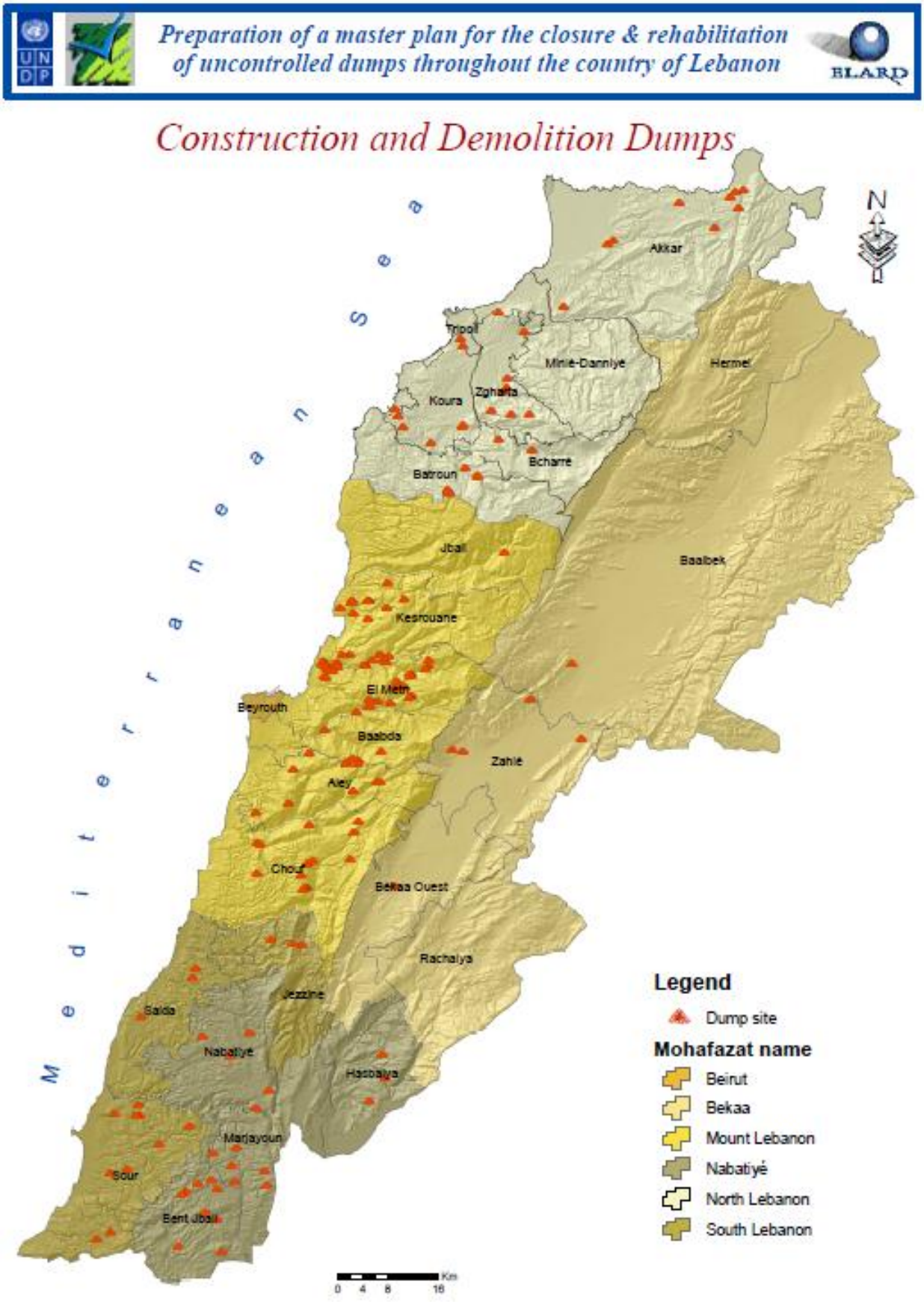


Figure 2-3 Location of CDW Dumps over the Lebanese Territory

2.3. GIS DATABASE GENERATION

Once the survey was completed and the data standardized and thoroughly subjected to QA/QC, the completed characterization form was transferred into a GIS based format.

Coordinates of the 670 dump sites were converted geographically into spatial data. The rest of the database was converted into Geodatabase and appended with the XY_spatial data. To be able to display the data over a wide variety of existing spatial data, a coordinate transformation from Geographical coordinate to Lambert conformal conic projection was conducted on the dump- sites. The dump site data was draped on the caza distribution and a primary key map tips with HTML popup was applied in order to facilitate the spatial display along with the database. One can either use the  to view dump ID on the fly (Figure 2-4) or can use the  to view and compare different dumps together (Figure 2-5).

Moreover, one can use the  icon to view the related photos for each dump.

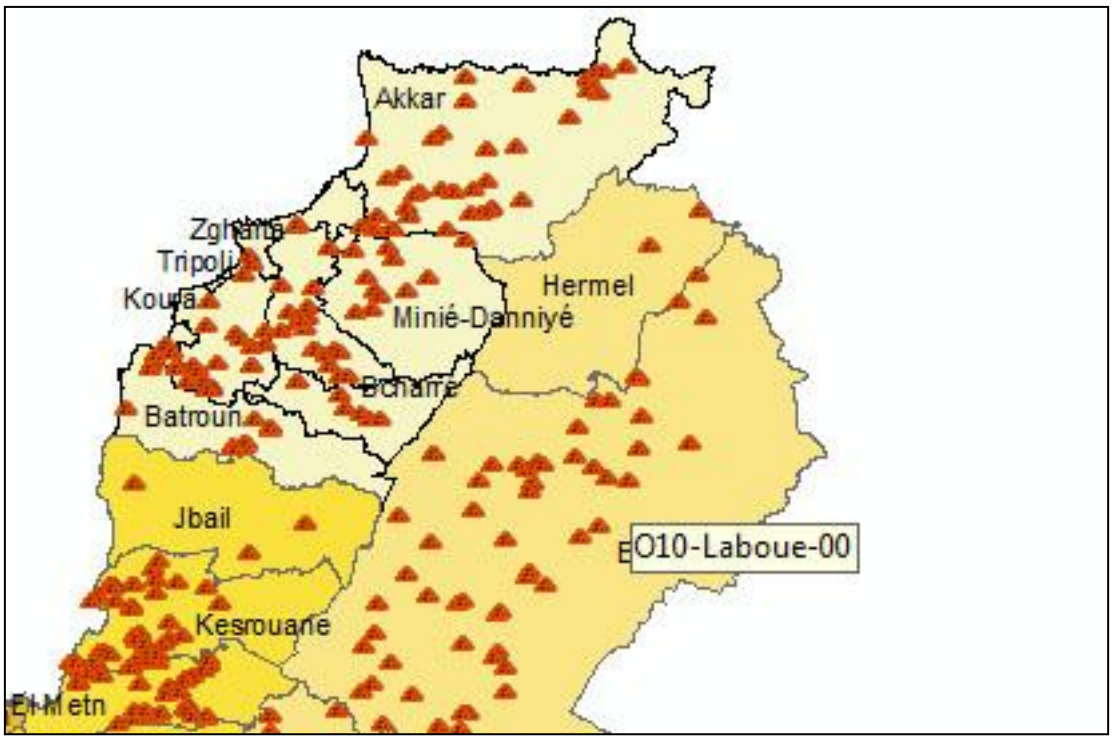


Figure 2-4 Snapshot from the GIS Project

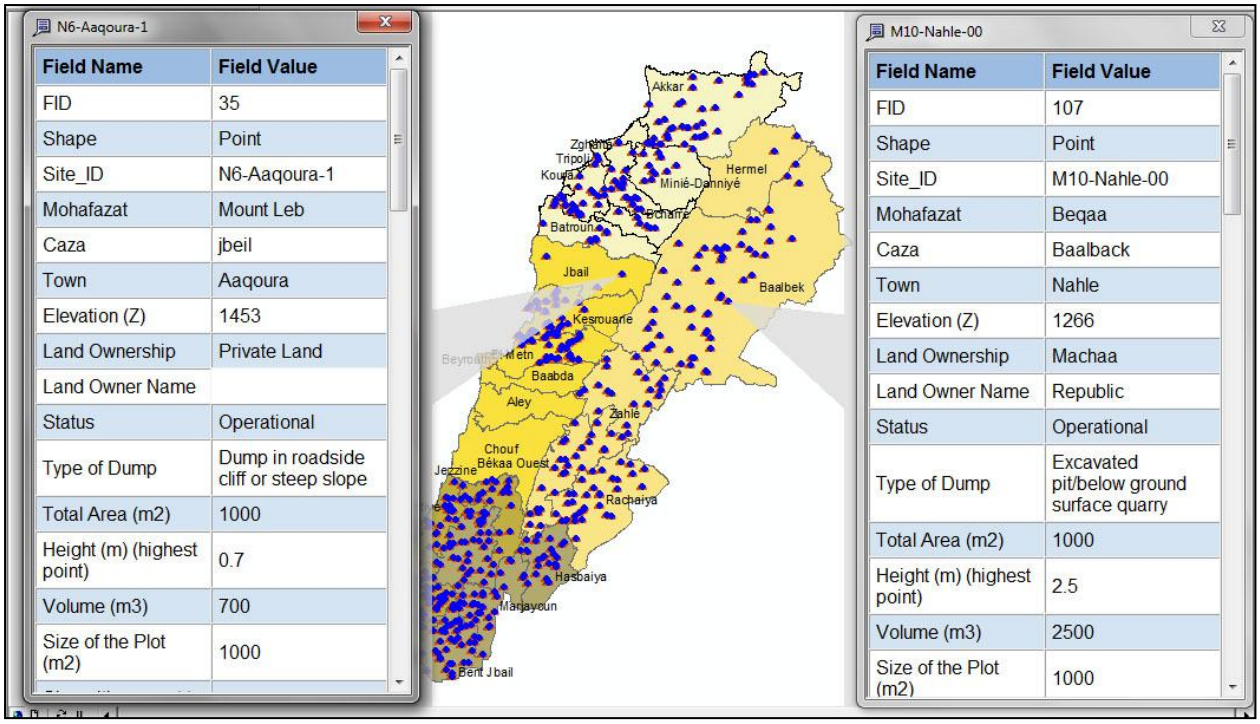


Figure 2-5 Snapshot Showing the Use of HTML Popup Option

3. PRIORITIZATION

3.1. METHODOLOGY

Identifying priority dumps for rehabilitation is a complex process which requires taking into account several social, environmental, and technical parameters. As such, it requires the processing of a massive amount of spatial data. Various methods *(Yoon et al., 1995; Leao et al., 2004; Pellow, 2004; Calvo et al., 2007; Rahman et al., 2008; Ekmekçioğlu et al., 2010; Junggoth et al., 2010; Şener et al., 2010)* have been consulted within the scope of this study in order to present an integrated risk based approach for developing a decision-making tool for dumpsite prioritization and rehabilitation. The selected approach reframes and relates important parameters for dumpsite prioritization under the Geographical Information System (GIS) umbrella.

The adopted approach involved the development of a Prioritization Decision Tool (PDT) for dumpsite rehabilitation which consisted of the following:

1. Selecting a number of risk-indicating attributes for the evaluation of dumpsites;
2. Assigning a weight to each selected attribute based on its significance and overall impact;
3. Assigning a sensitivity grade for each attribute based on collected data;
4. Calculating a Risk Sensitivity Index (RSI) for each dumpsite based on assigned attributes, weights, and sensitivity grade.

Two (2) different models have been developed to separately address MSW and CDW dumps, as these are characterized by very different features.

The following sub-sections explain each of the steps followed in the model development and application process.

3.1.1. Selection of Attributes

A large set of characteristic data was collected for each dump as part of the Project's survey phase. However, these needed to be restricted to a smaller number of features reflecting "priority" attributes which would guide the prioritization process.

Ten (10) attributes were thus selected as follows (*also see* Table 3-2):

- Volume of waste at site (m^3);
- Geology;
- Hydrology;
- Distance to urban areas (m);
- Quantity of waste currently dumped at site (t/d);
- Presence of alternatives;
- Open burning of waste;
- Dump visibility;
- Depth of filling of waste (m); and
- Duration of exposure (years).

As to CDW dumps, the following eight (8) attributes were considered:

- Volume of waste at site
- Visibility
- Hydrology
- Distance to urban areas
- Presence of alternatives/intended use
- Status
- Geology
- Duration of exposure

Scores for some of these attributes (model parameters) were obtained based on field survey results (such as volume of waste, quantity of waste, age of filling). However, attributes such as geology and hydrology required modeling under GIS environment so as to confirm and complete observations collected during field visits.

Each of the attributes listed above, as well as the method used to assign them their respective sensitivity grades, is further described below:

1. **Volume of waste at site (m^3):** The volume of wastes for each dump was measured directly at the site. This was done using a GPS for the area of dumps measurements. The height was deduced through bearing using geological compass. Volumes of the 670 dumps ranged between 1 and 375,000 m^3 and were divided into 4 classes: less than 10,000 m^3; between 10,000 and 50,000 m^3; between 50,000 and 100,000 m^3; and more than 100,000 m^3. This classification was based mainly on the field data gathered and comparison and classification of the data.
2. **Geology** (Figure 3-1)**:** This attribute was used to reflect the potential environmental impact on groundwater represented by the **Lithology**; 70% of the overall weighing factor, and **Faults & Lineaments density**; 30% of the overall weighing factor of the Geology attribute.

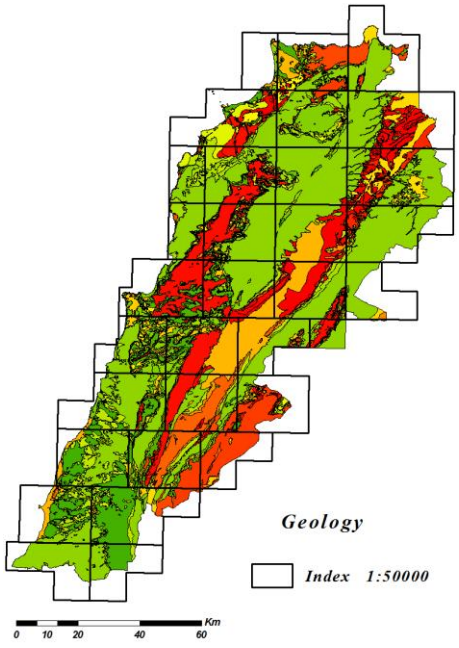


Figure 3-1 Appending the 27 geological sheet maps of 1: 50 000

a) Lithology: Lithological formations or rock facies have an important influence on infiltration rates and govern several effects on drainage networks and fracturing systems (Seelman, 1983; El-Baz and Himida, 1995; Ibrahim and Ammar, 2000). They were extracted through appending 27 sheets of 1: 50 000 geological map of Lebanon (Dubertret, 1955) (Figure 3-1). Lithological formations were classified in function of their infiltration capacity (Table 3-1) and intersected with the dump sites layer. The results were verified and compared with the data gathered in the field.

Table 3-1 Distribution of Lithological Formation According to Infiltration

INFILTRATION CAPACITY	GEOLOGICAL FORMATION (AGE)	EFFECTIVE INFILTRATION ELEMENTS
Very high (I)	Upper Aptian (C_{2b}), Cambrian (J_4), Callovian (J_6)	Secondary porosity (cracks & joints) of carbonate rock, plus high karstification
High (II)	Mio-Pliocene (Mp), Luticien (e_1), Perician (e_2), Cenomanian (C_4), Portoladian (J_7)	Secondary porosity, different forms of karstification and presence of some marl intercalations
Moderate (III)	Turonian (C_5), Lower Aptian (C_{2a}), Neocomian (C_1), Oxfordian (J_5)	Clay contents and jointing systems
Slightly moderate to low (IV)	Quaternary (Q), Pliocene (P), Vendobian (m_2), Pordogalian ($m_{1)}$, and Basalts (B), Senonian (C6), Albian (C3)	Considerable clayey content

b) Faults and lineaments density: Faults and lineaments, representing the tectonic factor, play an important role in defining fractured zones revealing different infiltration rates. They were extracted through visual and automated interpretations of Landsat 7 ETM satellite imagery (30 m) acquired in March 2005 (Figure 3-2). To achieve this, various steps of image enhancement were undertaken on both single and multi-bands consisting of sharpness, contrasting and directional filtering. The thermal band (120 m) was also considered, providing optimum information in detecting wet horizons that trace fractured zones carrying water. It is important to mention that the extraction process has considered only lineaments representing existing fractures in rock formations, without taking into account those related to linear artificial (man-made) and counterfeit features. This was done through overlapping the produced lineaments map with the relevant topographic maps, with special reference to linear objects such as roads, pipelines and terraces.

The "faults and lineaments" frequency density Lf, representing the visible number of faults and lineaments per unit area, was calculated by applying the following equation (Greenbaum, 1985):

Equation 3

$$L_f = \frac{\sum L_{ns}}{A}$$

Where Σ L_{ns} is the total number of lineaments, and A is the area in Km^2

Figure 3-2 Lineament Map Extracted from Satellite

To calculate this equation, a sliding window method was applied on the produced faults and lineaments map. This is done by dividing the study area into a grid mesh of equidistant cells. Taking into account that the size of the cells is depending on diverse factors (e.g. distribution appearance of linear features), a cell of 1 km x 1 km was considered. The number of linear segments was counted for each cell. Each obtained number was plotted in the mid of the cell. Therefore, the average value of each four neighboring cells was calculated and the result was plotted on the intersection point of the four cells (Figure 3-3).

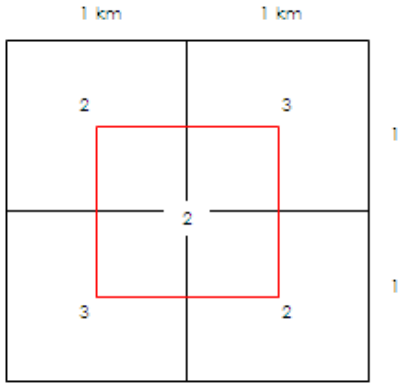


Figure 3-3 Sliding Window Method for Frequency Densities of Faults and Lineaments Calculation

From the plotted values, a point theme layer was created using a krigging interpolation method. Each point holds the mean sum number of lineament segments in the four neighboring cells, thus resulting in a "floating" surface grid representing the lineament frequencies (Figure 3-4). The resultant map was intersected with the point dump maps to allocate for each dump its corresponding Fault-lineament density category that it falls in.

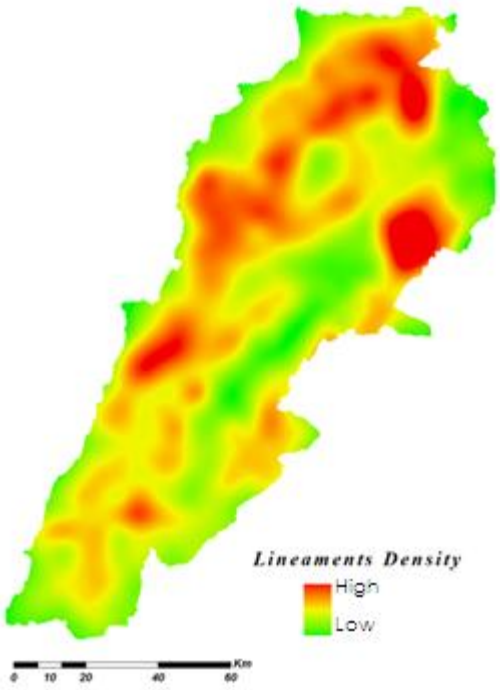


Figure 3-4 Fault - Lineament Density Map

3. **Hydrology:** According to the literature review (Dorhofer and Siebert, 1998; Knots et al., 2005; Nas el at., 2008), dumpsites should not be placed near any water surfaces (rivers, streams, and springs). To reflect this attribute (Hydrology) two themes were considered: distance to drainage (rivers and streams), and distance to springs, having an 80% and 20% of influence respectively on the Hydrology attribute.

    a) Distance to spring: The rivers and drainage were extracted from the topographic maps of Lebanon 1: 50 000 scale using heads-up digitizing. After appending, all digital blue line maps, a distance to line approach was conducted giving a continuous raster data file (Figure 3-5). The resultant was then intersected with the spatial distribution of the dump sites and collected in the dumps database.

    In the dumps database the distance to drainage was categorized in 4 classes: more than 200m; between 200 and 100m; between 100 and 50m; and less than 50m respectively.

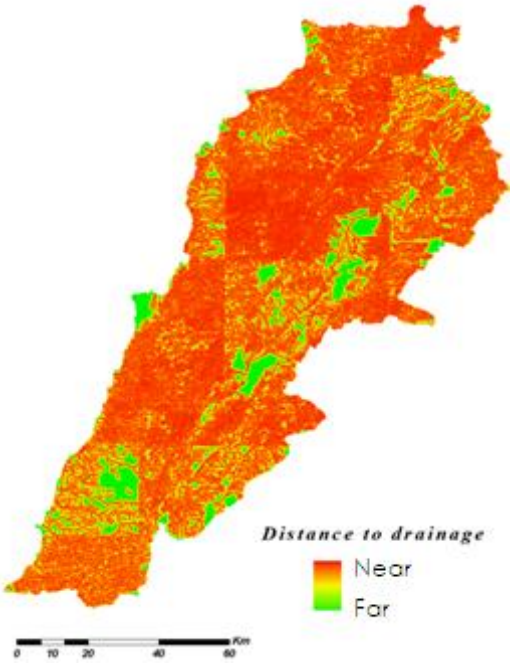


Figure 3-5 Distance to Drainage Line Raster Data

b) Distance to springs: All existing spring on the topographic sheets of 1: 50 000 for Lebanon were plotted and the distance to springs procedure was calculated (Figure 3-6). Following the same procedure of distance to drainage line, the distance to springs from the dumpsites was grouped in four classes (Table 3-1).

Figure 3-6 Distance to Spring Raster Data

4. **Distance to urban areas:** The map of urban agglomeration was plotted in GIS and the distance to urban areas was established. This in turn was overlapped with the Dumpsites point location layer to include the distance of each dump to urban areas. The distance of dumpsites to urban agglomeration was then classified into four classes more than 1000m; between1000 and 500 m; between 500and 250 m; and less than 250m.
5. **The quantity of waste currently dumped at site (t/d)** was collected during the field campaigns, introduced in the database and distributed among four classes: less than 10 t/d; between 10 and 50 t/d; between 50 and 100 t/d; and more than 100 t/d respectively. This factor is very important to categorize the size of an active dump and to differentiate it from an abandoned dumpsite.
6. **Presence of alternatives:** after consultation with the municipalities, each site was assigned one of four categories for this attribute: No alternatives, working on alternatives solution & funding, alternatives under construction, and alternative operational. The presence of an alternative solution is a very critical factor for the decision making process to close or rehabilitate a dump. Absence of an alternative solution will get a low value for sensitivity (0-0.25) while the presence of an operational alternative would receive a high sensitivity value (0.75 to 1.0).
7. **Open burning of waste:** score of this attribute to each site was defined following observations during site visit and discussions with residents and municipal members. A value of 0.25 was assigned to dumpsites where waste is being burned while a value of 0.75 was assigned to dumpsites where waste is piled up and not burned. When waste is burned, the volume of waste in the dump is reduced and its biodegradability is also reduced, consequently lowering the relative urgency for rehabilitation (from a biogas generation and leachate pollution perspective)[16].
8. **Visibility:** score of this attribute to each site was defined based on the field visits. A value of 0.25 was assigned for the sensitivity value when a dump is not visible from the main road and from the urban areas as compared to a sensitivity value of 0.75 for a dump that is clearly visible from the main road and urban areas.
9. **Depth of filling of waste (m):** the depth of filling waste was measured through bearing using geological compass and reclassified in the dump database into four classes: less than 1m; between 1 and 5m; between 5 and 10m; and more than 10m respectively.
10. **Duration of dump exposure (in years):** This information was collected during the field surveys and represents the overall duration the dump has been in existence and hence exposing potential receptors to its impacts; sites were classified in 4 classes for this attribute: less than 10 years; between 10 and 20 years; between 20 and 30 years; more than 30 years.

[16] It is to be noted that the Ministry of Environment considers open burning of waste as a highly polluting practice and strongly opposes its application. Open burning is here seen from a volume reduction perspective and its consideration is strictly restricted to the prioritization exercise's logic.

3.1.2. Attribute Tables

As explained above, ten (10) attributes were selected for MSW dump prioritization, out of which eight (8) were considered for CDW dumps prioritization. These attributes were each assigned a specific "weight" reflecting the relative significance of their associated environmental impact. Weights ranged from 1 to 10 for MSW dumps, and from 1 to 8 for CDW dumps. Each attribute was then given a "sensitivity grade" varying from 0 to 1 and divided into 4 quarters or ranges.

Table 3-2 below displays all ten (10) attributes selected for MSW dumps while the following table (Table 3-3) displays CDW dumps attributes; along with their associated weights and sensitivity grades.

Table 3-2 MSW Dumps Attribute Table

ATTRIBUTE		WEIGHING FACTOR	0.0-0.25	0.25-0.5	0.5-0.75	0.75-1.0
Total quantity of waste at site (m3)		10	<10,000 m3	10,000 - 50,000m3	50000 - 100000 m3	>100,000 m3
Geology	Lithology (70%)	9	Considerable to high clay content	Clay contents and jointing systems	Secondary porosity, different forms of karstification and presence of some marl intercalations	Secondary porosity (cracks & joints) of carbonate rock, plus high karstification
	Faults & lineaments density (segment/km2) (30%)		<10	10-15	15-20	> 20
Hydrology	Distance to drainage line (80%)	8	>200m	200-100m	50-75 m	<50m
	Distance to springs (20%)		>200m	200-150m	150-100 m	<100 m
Distance to urban areas		7	> 1000 m	1000 - 500 m	250 - 500 m	<250 m
Quantity of waste currently dumped at site (t/d)		6	<10 t/d	10-50 t/d	50 - 100 t/d	>100 t/d
Presence of alternatives		5	No Alternatives	Working on alternative solution & funding	Alternative under construction	Alternative operational
Open burning of waste		4	Burned		Not Burned	
Visibility		3	Not visible		Visible	
Depth of filling of waste (m)		2	<1m	1 - 5 m	5-10 m	>10 m
Duration of dump exposure (years)		1	< 10 year	10-20 years	20-30 years	>30 years

Table 3-3 CDW Dumps Attribute Table

ATTRIBUTE		WEIGHTING FACTOR	0.0-0.25	0.25-0.5	0.5-0.75	0.75-1.0
Volume of waste at site (m3)		8	<10,000 m3	10,000 - 50,000m3	50000 - 100000 m3	>100,000 m3
Visibility		7	Not visible		Visible	
Hydrology	Distance to drainage line (80%)	6	>200m	200-100m	50-75 m	<50m
	Distance to springs (20%)		>200m	200-150m	150-100 m	<100 m
Distance to urban areas		5	> 1000 m	1000 - 500 m	250 - 500 m	<250 m
Presence of alternatives/intended use		4	No alternatives/no plans	Working on alternative solution & funding	Alternative under construction	Alternative operational
Status (Abandoned/Operational)		3	Abandoned		Operational	
Geology	Lithology (70%)	2	Considerable to high clay content	Clay contents and jointing systems	Secondary porosity, different forms of karstification and presence of some marl intercalations	Secondary porosity (cracks & joints) of carbonate rock, plus high karstification
	Faults & lineaments density (segment/km2) (30%)		<10	10-15	15-20	> 20
Duration of dump exposure (yrs)		1	< 10 year	10-20 years	20-30 years	>30 years

3.1.3. RSI Calculation

The Risk Sensitivity Index (RSI) was calculated for each dump by adding all attributes after multiplying each sensitivity grade (class) by its weight respectively (Equation 4).

Equation 4

$$L_f = \frac{\sum L_{ns}}{A}$$

Where:

W_i: is the weightage of the i^{th} variable ranging from 1-10
S_i: Sensitive index of the i^{th} variable ranging from 0-1
RSI: Risk Sensitivity Index variable ranging from Minimum 0 to Maximum 55

Nevertheless, data could not be combined unless they measured the same values. For instance, it is not possible to combine data corresponding to measured values in years (age of filling) and values related to quantities of waste dumped at sited holding units in tons per day. Moreover, data values gathered in the dumpsites database are of two types, being either categorical (such as lithology, visibility, and age of filling) or numerical (such as lineaments, distance to roads, and depth of filling). Categorical data were thus reclassified, while numerical floating values were either plotted linearly or exponentially to unify the rating categories and assigned utilities for each class in its corresponding attribute.

Reclassification of the geology attribute normalized the categorical values of the predefined four classes. Accordingly "considerable to high clay content" scored "0.15" , Clay contents and jointing systems scored "0.35"; "Secondary porosity, different forms of karstification and presence of some marl intercalations" scored "0.65", and "secondary porosity (cracks & joints) of carbonate rock, plus high karstification" obtained the highest score "0.85". The same procedure for assigning utility numbers in categorical classes was used with exception of Visibility and Open Burning attributes where the only two classes (visible, not visible), (Burned, Not burned) were assigned 0.25 and 0.75 respectively.

On the other hand, a linear equation was applied to normalize the numerical values of each class in the corresponding attribute (Figure 3-7; Equation 3).

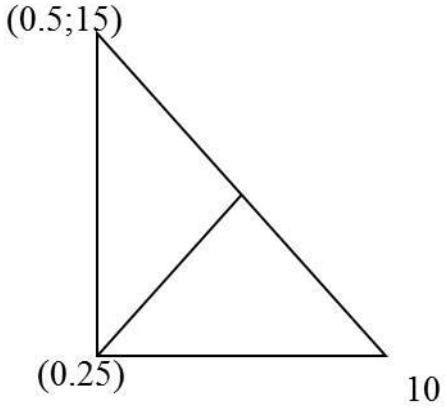


Figure 3-7 Example of Normalizing Values for Lineaments Ranging from 10 to 15

Equation 5

$$Y = ax + b$$

Where
Y: is the normalizing value
a: is the length of the quadrant portion
x: is the value of the attribute divided by the maximum value held by this same attribute
b: is the minimal value of the class quadrant

For example, if the total quantity of the waste at site is 20,000 m^3 then It falls in the second class quadrant (Table 2-1), i.e. between 0.25 –0.5. Thereof applying Equation 3 will give the following value:

a= 0.25
x= 20000/50000
b= 0.25
Y = ((20 000 m^3 * 0.25)/50 000 m^3) + 0.25= **0.35**

A Prefix of "M" was given for the new established fields (with new columns being added to the databases). Risk Sensitivity Indices (RSI) were then calculated accordingly, based on Equation 5 above.

A site with a higher score indicates more risk to human health and the environment, and suggests that it requires a more urgent intervention. Conversely, when the total RSI score of a dumpsite decreases, the priority for its rehabilitation decreases.

3.2. RESULTS

Once the prioritization model was run, dumps could be classified and represented on digital maps as per their RSI.

Table 3-4 and Table 3-5 below provide the number of dumps and total volume of waste per RSI range for MSW and for CDW dumps. Figure 3-8 and Figure 3-9 show the resulting RSI of dumpsites over the Lebanese territory.

While all dumps and their RSI can be viewed in the GIS and excel databases (Appendices A and B), the twenty (20) top ranking dumps are shown in Table 3-6 and Table 3-7.

These twenty priority dumps:

- Form an aggregate volume which represents respectively 70% and 75% of the total volume of MSW and CDW dumps (for MSW and CDW dumps combined, the 40 priority dumps represent 71% of the total volume);
- Cover all dumps comprised in the first range of priority (Table 3-4 and Table 3-5) and an additional share of dumps from the second range (around 8% for MSW dumps and 25% for CDW dumps);
- Represent respectively 4% and 12% of total number of MSW and CDW dumps (around 5% in total); and
- Include those dumps with RSI values exceeding respectively 40% and 50% of maximum attainable RSIs for MSW and CDW dumps.

Table 3-4 Number and Total Volume of MSW Dumps per RSI Range

RSI RANGE	NUMBER OF DUMPS	TOTAL VOLUME (m^3)
25-55	13	3,281,550
18-25	95	693,434
15-18	118	350,556
12-15	151	277,261
6-12	127	401,275
Total	**504**	**5,004,076**

Table 3-5 Number and Total Volume of CDW Dumps per RSI Range

RSI RANGE	NUMBER OF DUMPS	TOTAL VOLUME (m^3)
20-36	8	959,080
16-20	48	523,560
12-16	92	216,435
10-12	13	22,121
8-10	5	9,985
Total	**166**	**1,731,180**

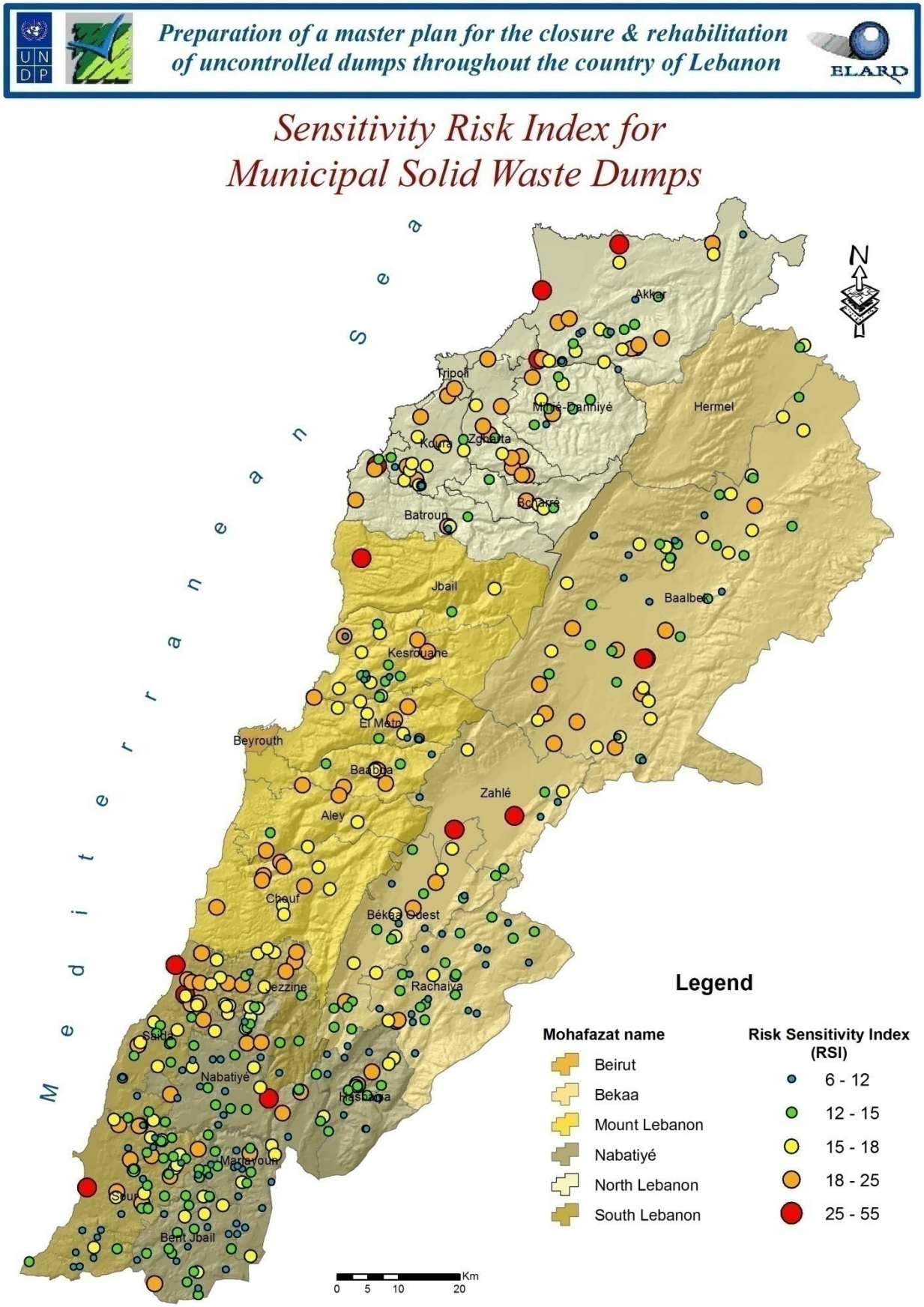


Figure 3-8 Risk Sensitivity Index (RSI) Map of MSW Dumps over the Lebanese territories

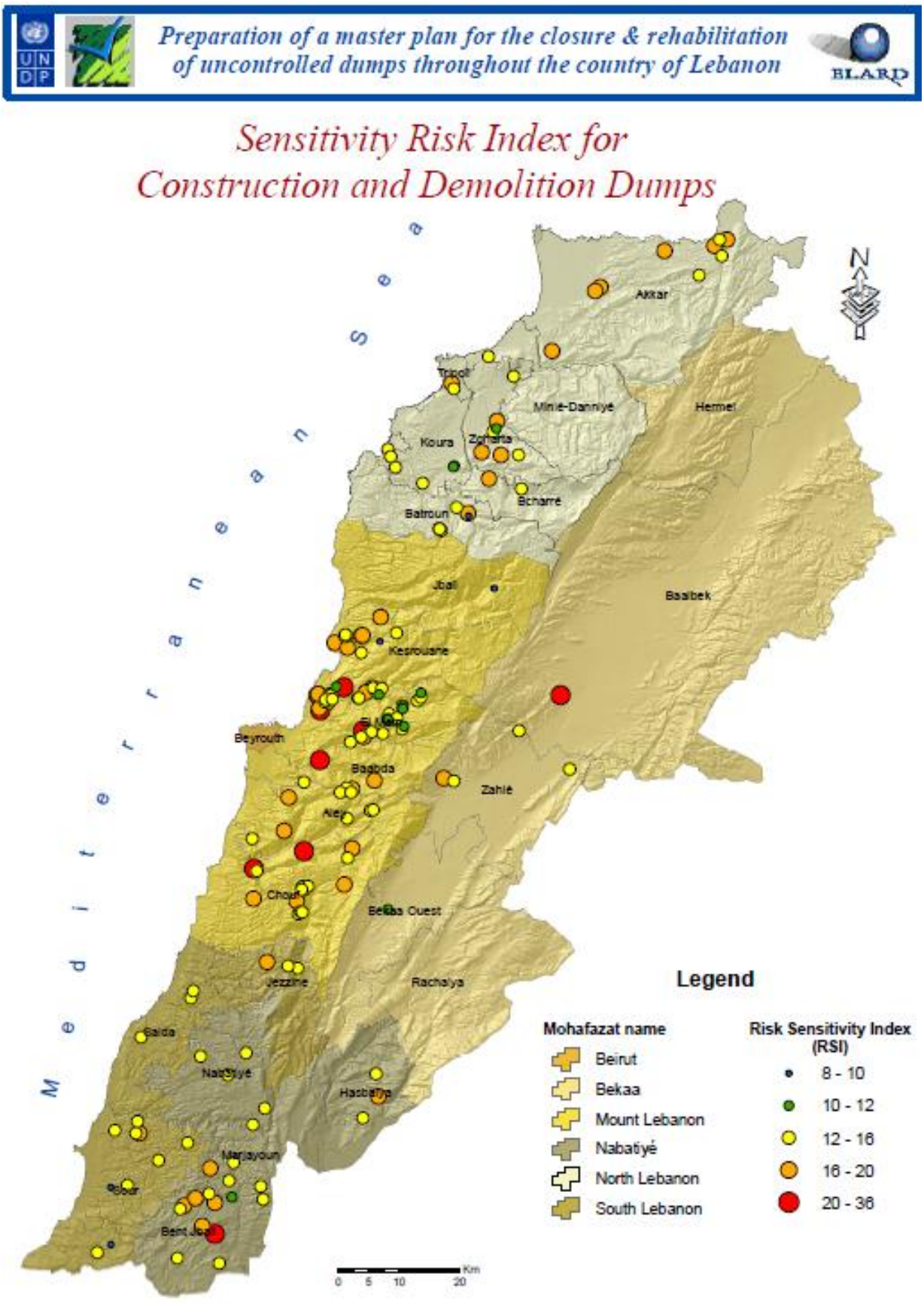


Figure 3-9 Risk Sensitivity Index (RSI) Map of CDW Dumps over the Lebanese territories

Table 3-6 20 Highest Ranked MSW Dumps

RANK	DUMP ID	MOUHARFAZA	CAZA	RSI SCORE
1	G-2-Saida	South	Saida	47.49
2	C1-Deir Qanoun El - Aain-01	South	Sour	36.97
3	N5-Hbaline-0	Mount Lebanon	Jbeil	35.12
4	T9-Srar-0	North	Akkar	33.88
5	R7-Adweh-0	North	Minieh	32.64
6	E4-Kfar Tibnit-00	Nabatieh	Nabatieh	32.08
7	J7-Barr Elias-00	Beqaa	Zahle	31.82
8	P5-Hamat-1	North	Batroun	30.54
9	M9-Baalback-02	Beqaa	Baalback	28.25
10	M9-Baalback-01	Beqaa	Baalback	27.74
11	J6-Qabb Elias-00	Beqaa	Zahle	27.05
12	G2-Ghaziye-00	South	Saida	25.98
13	S7-Mqaiteaa-0	North	Minyeh-donniye	25.62
14	R9-Fnaydek-0	North	Akkar	24.40
15	L8-Haouch el Refqa-00	Beqaa	Baalback	23.93
16	L4-Zouk Al Khrab-1	Mount Lebanon	Maten	23.65
17	J5-Rouayset El Ballout-0	Mount Lebanon	Baabda	23.57
18	K7-Timnine-00	Beqaa	Baalback	23.41
19	R8-Birkayel-0	North	Akkar	23.17
20	P7-Beslouqit-2	North	Zgharta	22.66

Table 3-7 20 Highest Ranked CDW Dumps

RANK	DUMP ID	MOUHAFAZA	CAZA	RSI SCORE
1	L8-Chmestar-01	Beqaa	Baalback	27.34
2	I4-Ammiq Ech Chouf-0	Mount Lebanon	Shouf	21.84
3	I4-Dmit-0	Mount Lebanon	Shouf	21.46
4	K4-Beit Meri-00	Mount Lebanon	Metn	21.35
5	B-3-Kounine-02	Nabatieh	Bent Jbeil	21.02
6	L4-Mtayleb-1	Mount Lebanon	Metn	20.98
7	K5-Mar Moussa Ed-Douar-0	Mount Lebanon	Metn	20.35
8	L5-Aain Er-Rihane-3	Mount Lebanon	Kisirween	20.08
9	L5-Qlaiaat-3	Mount Lebanon	Kisirween	19.88
10	L4-Zouk Al Khrab-2	Mount Lebanon	Metn	19.52
11	L4-Dik Al-Mahdi-0	Mount Lebanon	Metn	19.38
12	I5-Maaser Ech Chouf-0	Mount Lebanon	Shouf	19.28
13	E-5-Chebaa-01	Nabatieh	Hasbaya	18.62
14	L4-Zouk Mousbeh-7	Mount Lebanon	Kisirween	18.55
15	I4-Aatrine-1	Mount Lebanon	Shouf	18.22
16	L4-Zouk Al Khrab-4	Mount Lebanon	Metn	18.22
17	L4-Zouk Al Khrab-3	Mount Lebanon	Metn	18.21
18	M5-Kfar Yasine-0	Mount Lebanon	Kisirween	18.11
19	J5-Chbaniye-0	Mount Lebanon	Baabda	18.09
20	J4-Aaytat-0	Mount Lebanon	Aalay	17.91

3.3. SENSITIVITY ANALYSIS

Based on expert (MoE, UNDP, and ELARD) opinion and professional judgment, the prioritization model results seemed reasonable and consistent. Nonetheless, a sensitivity analysis exercise was conducted over the PDT model so as to verify, fine-tune and confirm its validity, as per the following paragraph. It is to be noted though that a rehabilitation plan was suggested to all surveyed dumps regardless of their ranking; the Master Plan as such remains therefore unaffected by prioritization outcomes.

The sensitivity analysis exercise consisted of interchanging MSW dumps weighing factors among attributes and running several tests accordingly. No changes were introduced to the

grades as these are subject to minimal uncertainty being statistically set based on collected data which was subjected to a thorough QA/QC.

Outcomes were then compared with the original model results. A series of fine-tuning measures were then implemented based on conclusions drawn.

Results of two of the sensitivity analysis rounds (Sensitivity Analysis "A" and Sensitivity Analysis "B"), with weights set as shown in Table 3-8 Original and Test Weights Used in Sensitivity Analysis "A"

Original Version

ATTRIBUTE	WEIGHT FACTOR
Total Quantity	10
Geology	9
Hydrology	8
Dist. to UA	7
Quantity dumped t/d	6
Alternatives	5
Open burning	4
Visibility	3
Filling depth	2
Exposure time	1

Test Version

ATTRIBUTE	WEIGHT FACTOR
Total Quantity	**9**
Geology	**8**
Hydrology	**10**
Dist. to UA	**7**
Quantity dumped t/d	**5**
Alternatives	**6**
Open burning	**4**
Visibility	**2**
Filling depth	**3**
Exposure time	**1**

Table 3-9 Results from Sensitivity Analysis "A"

Original Version

RANK	DUMP ID	RSI SCORE
1	G-2-Saida	47.49
2	C1-Deir Qanoun El - Aain-01	36.97
3	N5-Hbaline-0	35.12
4	T9-Srar-0	33.88
5	R7-Adweh-0	32.64
6	E4-Kfar Tibnit-00	32.08
7	J7-Barr Elias-00	31.82
8	P5-Hamat-1	30.54
9	M9-Baalback-02	28.25
10	M9-Baalback-01	27.74
11	J6-Qabb Elias-00	27.05
12	G2-Ghaziye-00	25.98
13	S7-Mqaiteaa-0	25.62
14	R9-Fnaydek-0	24.40
15	L8-Haouch el Refqa-00	23.93
16	L4-Zouk Al Khrab-1	23.65
17	J5-Rouayset El Ballout-0	23.57
18	K7-Timnine-00	23.41
19	R8-Birkayel-0	23.17
20	P7-Beslouqit-2	22.66

Test Version

RANK	DUMP ID	RSI SCORE
1	G-2-Saida	47.60
2	C1-Deir Qanoun El - Aain-01	36.60
3	N5-Hbaline-0	35.89
4	T9-Srar-0	33.76
5	R7-Adweh-0	32.21
6	J7-Barr Elias-00	31.82
7	E4-Kfar Tibnit-00	30.58
8	P5-Hamat-1	29.72
9	M9-Baalback-02	27.63
10	M9-Baalback-01	27.59
11	J6-Qabb Elias-00	26.30
12	G2-GhaziyΘ-00	26.13
13	S7-Mqaiteaa-0	25.61
14	L8-Haouch el Refqa-00	25.20
15	R9-Fnaydek-0	24.90
16	L4-Zouk Al Khrab-1	24.33
17	J5-Rouayset El Ballout-0	24.12
18	K7-Timnine-00	24.03
19	E-5-Aain Qinia-00	23.55
20	M9-Haouch Tall Safia-00	23.17

Table 3-10 and Table 3-8 below, came as exposed in Table 3-11 and Table 3-9 (for the 20 highest ranked MSW dumps) .

In both trials, the first 13 dumps (1st range of priority) remain the same as in the Original setup. Additionally, only the highlighted dumps (2 in Sensitivity Analysis A and 4 in Sensitivity Analysis B) do not figure in the original version.

Table 3-8 Original and Test Weights Used in Sensitivity Analysis "A"

Original Version

ATTRIBUTE	WEIGHT FACTOR
Total Quantity	10
Geology	9
Hydrology	8
Dist. to UA	7
Quantity dumped t/d	6
Alternatives	5
Open burning	4
Visibility	3
Filling depth	2
Exposure time	1

Test Version

ATTRIBUTE	WEIGHT FACTOR
Total Quantity	**9**
Geology	**8**
Hydrology	**10**
Dist. to UA	**7**
Quantity dumped t/d	**5**
Alternatives	**6**
Open burning	**4**
Visibility	**2**
Filling depth	**3**
Exposure time	**1**

Table 3-9 Results from Sensitivity Analysis "A"

Original Version

RANK	DUMP ID	RSI SCORE
1	G-2-Saida	47.49
2	C1-Deir Qanoun El - Aain-01	36.97
3	N5-Hbaline-0	35.12
4	T9-Srar-0	33.88
5	R7-Adweh-0	32.64
6	E4-Kfar Tibnit-00	32.08
7	J7-Barr Elias-00	31.82
8	P5-Hamat-1	30.54
9	M9-Baalback-02	28.25
10	M9-Baalback-01	27.74
11	J6-Qabb Elias-00	27.05
12	G2-Ghaziye-00	25.98
13	S7-Mqaiteaa-0	25.62
14	R9-Fnaydek-0	24.40
15	L8-Haouch el Refqa-00	23.93
16	L4-Zouk Al Khrab-1	23.65
17	J5-Rouayset El Ballout-0	23.57
18	K7-Timnine-00	23.41
19	R8-Birkayel-0	23.17
20	P7-Beslouqit-2	22.66

Test Version

RANK	DUMP ID	RSI SCORE
1	G-2-Saida	47.60
2	C1-Deir Qanoun El - Aain-01	36.60
3	N5-Hbaline-0	35.89
4	T9-Srar-0	33.76
5	R7-Adweh-0	32.21
6	J7-Barr Elias-00	31.82
7	E4-Kfar Tibnit-00	30.58
8	P5-Hamat-1	29.72
9	M9-Baalback-02	27.63
10	M9-Baalback-01	27.59
11	J6-Qabb Elias-00	26.30
12	G2-GhaziyΘ-00	26.13
13	S7-Mqaiteaa-0	25.61
14	L8-Haouch el Refqa-00	25.20
15	R9-Fnaydek-0	24.90
16	L4-Zouk Al Khrab-1	24.33
17	J5-Rouayset El Ballout-0	24.12
18	K7-Timnine-00	24.03
19	E-5-Aain Qinia-00	23.55
20	M9-Haouch Tall Safia-00	23.17

Table 3-10 Original and Test Weights Used in Sensitivity Analysis "B"

Original Version

ATTRIBUTE	WEIGHT FACTOR
Total Quantity	10
Geology	9
Hydrology	8
Dist. to UA	7
Quantity dumped t/d	6
Alternatives	5
Open burning	4
Visibility	3
Filling depth	2
Exposure time	1

Test Version

ATTRIBUTE	WEIGHT FACTOR
Total Quantity	**7**
Geology	**8**
Hydrology	**6**
Dist. to UA	**9**
Quantity dumped t/d	**10**
Alternatives	**5**
Open burning	**3**
Visibility	**4**
Filling depth	**2**
Exposure time	**1**

Table 3-11 Results from Sensitivity Analysis "B"

Original Version

RANK	DUMP ID	RSI SCORE
1	G-2-Saida	47.49
2	C1-Deir Qanoun El - Aain-01	36.97
3	N5-Hbaline-0	35.12
4	T9-Srar-0	33.88
5	R7-Adweh-0	32.64
6	E4-Kfar Tibnit-00	32.08
7	J7-Barr Elias-00	31.82
8	P5-Hamat-1	30.54
9	M9-Baalback-02	28.25
10	M9-Baalback-01	27.74
11	J6-Qabb Elias-00	27.05
12	G2-Ghaziye-00	25.98
13	S7-Mqaiteaa-0	25.62
14	R9-Fnaydek-0	24.40
15	L8-Haouch el Refqa-00	23.93
16	L4-Zouk Al Khrab-1	23.65
17	J5-Rouayset El Ballout-0	23.57
18	K7-Timnine-00	23.41
19	R8-Birkayel-0	23.17
20	P7-Beslouqit-2	22.66

Test Version

RANK	DUMP ID	RSI SCORE
1	G-2-Saida	48.16
2	C1-Deir Qanoun El - Aain-01	37.13
3	N5-Hbaline-0	32.93
4	T9-Srar-0	32.74
5	E4-Kfar Tibnit-00	31.86
6	R7-Adweh-0	31.30
7	J7-Barr Elias-00	29.96
8	M9-Baalback-02	28.63
9	P5-Hamat-1	28.45
10	M9-Baalback-01	26.80
11	J6-Qabb Elias-00	24.67
12	S7-Mqaiteaa-0	24.59
13	G2-GhaziyΘ-00	24.17
14	L4-Zouk Al Khrab-1	22.98
15	R9-Fnaydek-0	22.91
16	K7-Timnine-00	22.69
17	I6-Ghazze-00	22.23
18	M9-Haouch Tall Safia-00	22.07
19	I4-Sirjbal-3	22.04
20	R9-Mishmesh-0	21.96

3.4. GIS INTEGRATION

After having integrated the whole database in a digital GIS form, an easy access interface was created for both Municipal Solid Waste (MSW) and Construction and Demolition Waste (CDW) dumps using ArcObjects**.** ArcObjects is the development platform for ArcGIS, as ArcObjects is built using Microsoft's COM (Component Object Model) technology, and it is possible to use any COM-compliant development language with ArcObjects to customize applications in ArcGIS.

The created interfaces allow running the Risk Sensitivity Index (RSI) according to the given weighing parameters for both MSW and CDW dumps. Additionally, users are given the option to change the weighing factor of each parameter and see how this will affect the total RSI scoring (Figure 3-10). Note that all tabs (except RUN) are dimmed because the RSI has not been calculated yet.

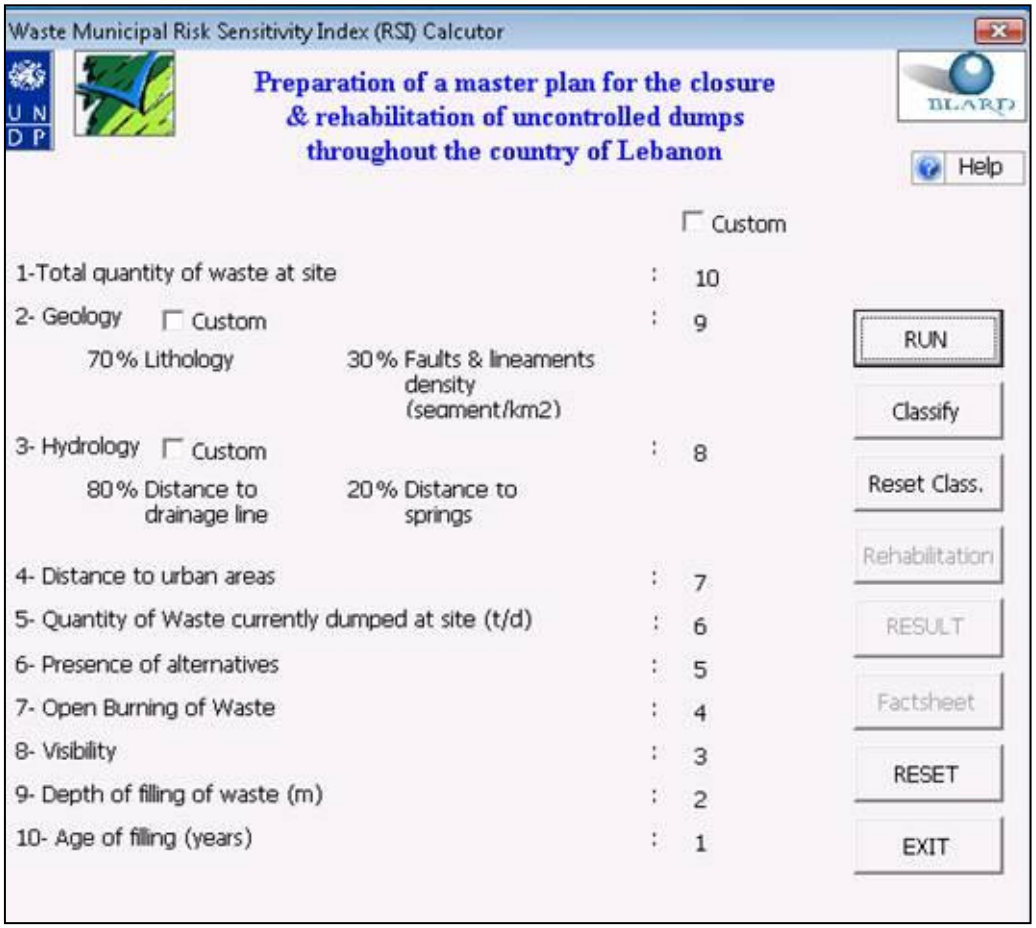


Figure 3-10 SWMRSI Weight Selection Interface

Codes were also developed to enable symbolizing and classifying the dumps according to the RSI score, in addition to a help button that displays different forms guiding the user through the interface model.

4. REHABILITATION

Remedial measures differ from one dump to the other based on the complexity of the case and the availability of alternative waste management solutions.

Seven remedial measures were considered for MSW dumps. These include:

8. Excavate, treat and transfer waste to waste treatment /sanitary landfill;
9. Transfer to a sanitary landfill/controlled dump;
10. Convert to a controlled dump or to a sanitary landfill;
11. Excavate, treat[17], and transfer;
12. Grade, cap and manage gases;
13. Grade, cap and manage gases and leachate; and
14. Group with other dumps and transfer to controlled dump.

Additionally, four remedial measures were considered for CDW dumps, consisting of:

8. Sorting, crushing and recycling;
9. Transfer to other priority dumps or to an approved C&D Landfill;
10. Grade surface, cover with soil and re-vegetate; and
11. Achieve intended use.

4.1. METHODOLOGY

The Rehabilitation Decision Tool (RDT) provides a methodology for the description and comparison of alternative remediation scenarios relying on the RSI. The RDT module procedure allows the user to describe and compare the following aspects:

- The post remediation site use and related socio-economic benefits;
- The remediation plan and related costs, time of interventions, performance reliabilities and environmental impacts (RSI);
- The reduction of the risk posed by contaminants in soil and groundwater (RSI), resulting from the simulated application of the remediation plan.

A set of indices identifies advantages and drawbacks of each scenario, such as the socioeconomic benefits for the selected post remediation land use, technological and logistical quality of the technological set, residual risk (spatial extension, average magnitude and magnitude reduction), total cost and duration of interventions, environmental impact.

Lower costs may be combined with longer intervention periods for the rehabilitation of the site; high treatment performances may lead, especially in case of large contaminated

[17] "Treat" might include sorting, composting, degasification, Waste to Energy (WtE) applications, etc…

volumes, to relevant environmental impacts; the most suitable site use may require very strict risk minimization targets and high remediation costs. The RDT is based on a decision tree module (that is used to determine the remedial measure needed for each site). A walkthrough the decision trees (Figure 4-1 and

Figure 4-2) would lead to the preferred remedial measure needed for each dump.

4.2. DECISION TOOL

Decision trees were used as decision support tools for identifying the most suitable rehabilitation option for each dump based on its characteristics.

Two decision trees were thus generated to properly address MSW dumps and CDW dumps. These were built based on a set of Yes/No questions, the answers to which would lead to one path or another, ultimately revealing the most adapted rehabilitation option.

Table 4-1 and Table 4-2 below list the set of questions raised within the decision trees, along with the main attribute each question refers to, and the criteria based on which one path would be taken over the other (the Yes or the No paths). Figure 4-1 and

Figure 4-2 follow, illustrating the two decision trees as modeled and run.

Table 4-1 MSW Dumps Decision Tree Explanation

QUESTION	REFERENCE ATTRIBUTE	CRITERIA FOR YES	CRITERIA FOR NO
Is a suitable landfill / controlled dump available?	-	When user inputs positive response	Always, unless user inputs a positive response
Is volume reduction required?	-	When user inputs positive response	Always, unless user inputs a positive response
Is land large enough?	-	Size with respect to plot >50%**	Size with respect to plot < 50%**
Is geologic formation favorable?	Geology*	M_geology < 0.25**	M_geology > 0.25**
Can waste still be disposed of in this land?	Land owner; Distance to urban areas*; Visibility*	Land owned by Municipality; M_dist_urb <0.35; and M_visibility <0.25 **	Land not owned by Municipality; M_dist_urb >0.35; and M_visibility >0.25 **
Does a WM alternative exist?	Presence of alternatives*	M_pres alt > 0.5**	M_pres alt < 0.5**
Is volume of waste large enough?	Volume*; Quantity*	M_volume_M > 0.5 or M_quantity 2 > 0.5 **	M_volume_M < 0.5 or M_quantity 2 < 0.5 **
Is geologic formation favorable?	Geology*	M_geology < 0.25 **	M_geology > 0.25**
Is remediation required?	Volume*; Quantity*	M_quantity < 0.2 and M_volume < 0.2**	M_quantity > 0.2 and M_volume > 0.2**

**refer to Attribute Table*

***refer to Sensitivity Grade results*

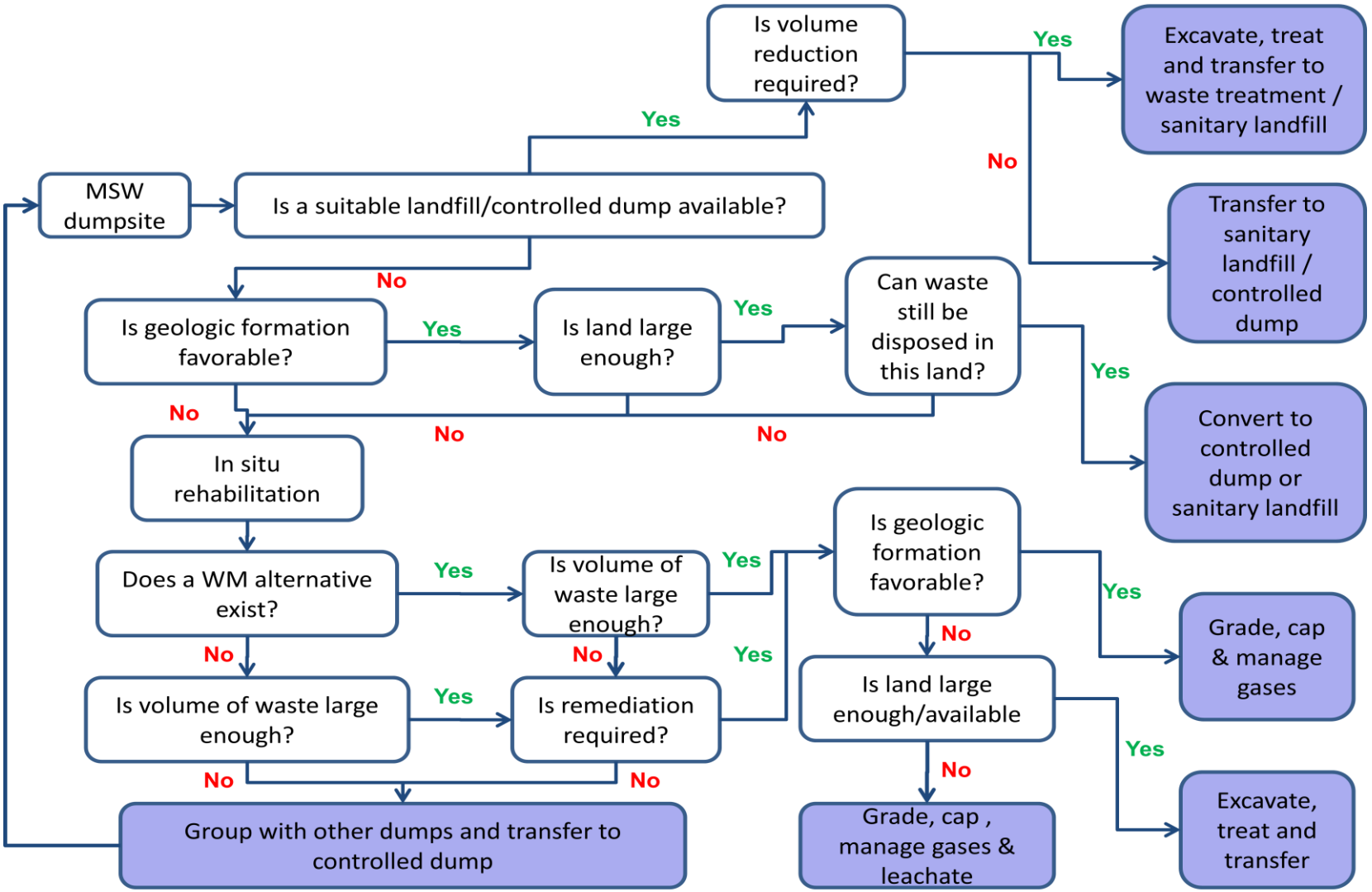


Figure 4-1 MSW Dumps Rehabilitation Options Decision Tree

Table 4-2 CDW Dumps Decision Tree Explanation

QUESTION	REFERENCE ATTRIBUTE*	CRITERIA** FOR YES	CRITERIA** FOR NO
Does an intended use of the dump exist?	Presence of alternatives	M_pres_alt >=0.5	M_pres_alt <=0.5
Is volume of waste large enough?	Volume	V>=50,000 m3	V<=50,000 m3
Is the dump highly visible?	Visibility	M_visibility >=0.5	M_visibility <=0.5
	Volume	10,000m3 <= V <=50,000 m3	V<10,000 m3 or V>50,000 m3
	Distance to urban areas	M_dist_urb >=0.5	M_dist_urb <= 0.5
	Distance to water bodies	N_hydrology>=0.494	N_hydrology<=0.494
Is the dump operational?	Status	Operational	Abandoned

**refer to Attribute Table*

*** refer to Sensitivity Grade results*

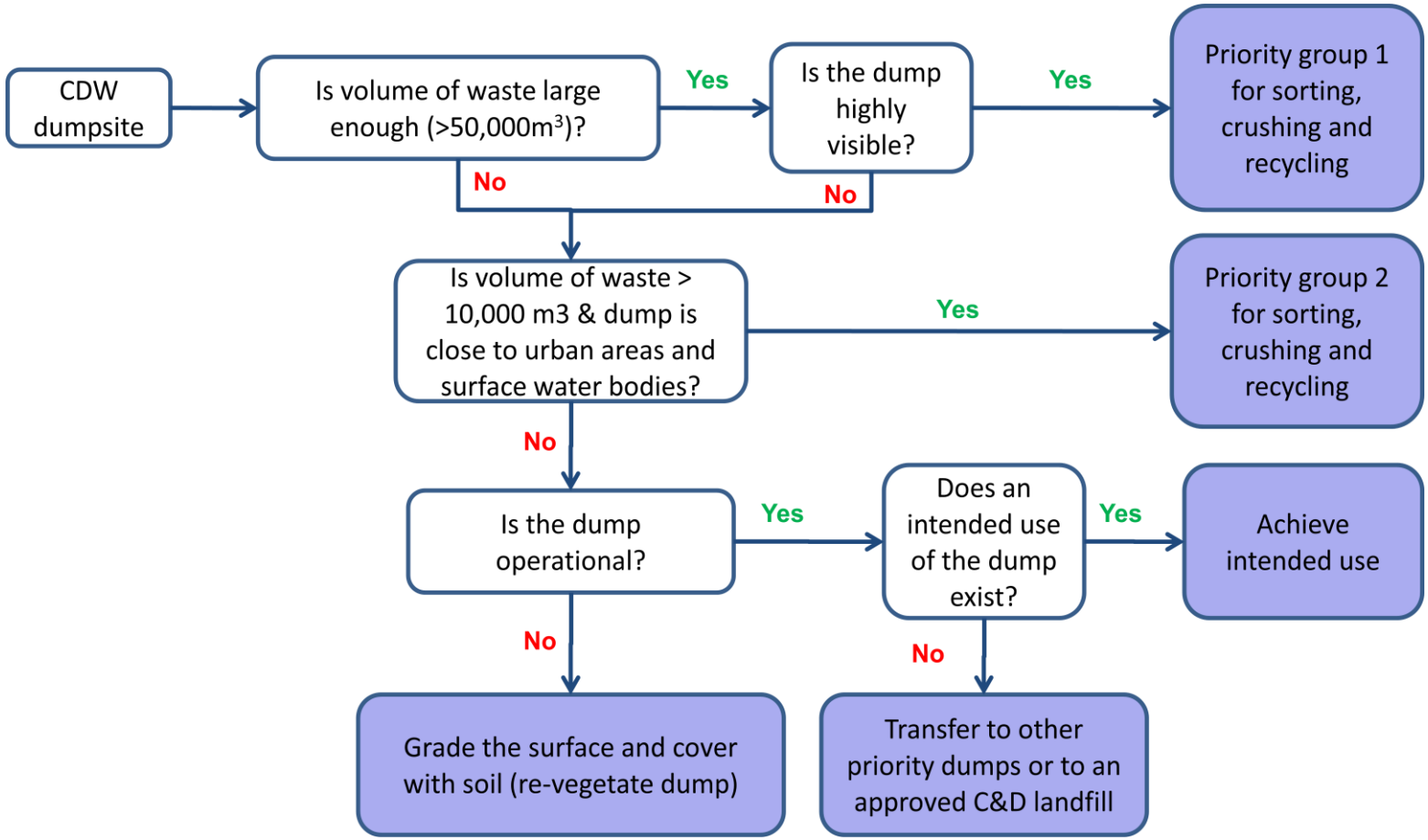


Figure 4-2 CDW Dumps Rehabilitation Options Decision Tree

4.3. RESULTS

Once the decision tree models were run, the most suitable rehabilitation option for each dump was automatically identified. Rehabilitation option results for all dumps are provided in excel format under Appendix B. Additionally, Table 4-3 and Table 4-3 below summarize the proposed rehabilitation plan for the twenty (20) highest ranked MSW and CDW dumps.

Table 4-3 Proposed Rehabilitation Plan for 20 MSW Priority Dumps

RANK	SITE_ID	RSI	PROPOSED REHABILITATION PLAN
1	G-2-Saida	47.49	Grade, cap, manage gases and leachate
2	C1-Deir Qanoun El - Aain-01	36.97	Grade, cap, manage gases and leachate
3	N5-Hbaline-0	35.12	Grade, cap, manage gases and leachate
4	T9-Srar-0	33.88	Grade, cap, manage gases and leachate
5	R7-Adweh-0	32.64	Grade, cap, manage gases and leachate
6	E4-Kfar Tibnit-00	32.08	Grade, cap, manage gases and leachate
7	J7-Barr Elias-00	31.82	Excavate, treat and transfer
8	P5-Hamat-1	30.54	Grade, cap, manage gases and leachate
9	M9-Baalback-02	28.25	Excavate, treat and transfer to waste treatment/sanitary landfill
10	M9-Baalback-01	27.74	Grade, cap and manage gases
11	J6-Qabb Elias-00	27.05	Grade, cap, manage gases and leachate
12	G2-GhaziyΘ-00	25.98	Grade, cap and manage gases
13	S7-Mqaiteaa-0	25.62	Grade, cap, manage gases and leachate
14	R9-Fnaydek-0	24.40	Grade, cap, manage gases and leachate
15	L8-Haouch el Refqa-00	23.93	Grade, cap, manage gases and leachate
16	L4-Zouk Al Khrab-1	23.65	Grade, cap and manage gases
17	J5-Rouayset El Ballout-0	23.57	Group with other dumps and transfer to controlled dump
18	K7-Timnine-00	23.41	Group with other dumps and transfer to controlled dump
19	R8-Birkayel-0	23.17	Grade, cap, manage gases and leachate
20	P7-Beslouqit-2	22.66	Group with other dumps and transfer to controlled dump

Table 4-4 Proposed Rehabilitation Plan for 20 CDW Priority Dumps

RANK	SITE_ID	RSI	PROPOSED REHABILITATION PLAN
1	L8-Chmestar-01	27.34	Achieve intended use *(enlarge road)*
2	I4-Ammiq Ech Chouf-0	21.84	Achieve intended use *(transform to a garden/plant trees)*
3	I4-Dmit-0	21.46	Priority Group 1 for Sorting, crushing and recycling
4	K4-Beit Meri-00	21.35	Priority Group 2 for Sorting, crushing and recycling
5	B-3-Kounine-02	21.02	Achieve intended use *(garden or playground)*
6	L4-Mtayleb-1	20.98	Achieve intended use *(building road)*
7	K5-Mar Moussa Ed-Douar-0	20.35	Achieve intended use *(agriculture)*
8	L5-Aain Er-Rihane-3	20.08	Achieve intended use *(road costruction)*
9	L5-Qlaiaat-3	19.88	Priority Group 1 for Sorting, crushing and recycling
10	L4-Zouk Al Khrab-2	19.52	Priority Group 2 for Sorting, crushing and recycling
11	L4-Dik Al-Mahdi-0	19.38	Priority Group 2 for Sorting, crushing and recycling
12	I5-Maaser Ech Chouf-0	19.28	Achieve intended use *(football court and parking)*
13	E-5-Chebaa-01	18.62	Priority Group 1 for Sorting, crushing and recycling
14	L4-Zouk Mousbeh-7	18.55	Achieve intended use
15	I4-Aatrine-1	18.22	Achieve intended use *(annex to football court)*
16	L4-Zouk Al Khrab-4	18.22	Priority Group 2 for Sorting, crushing and recycling
17	L4-Zouk Al Khrab-3	18.21	Transfer to other priority dumps
18	M5-Kfar Yasine-0	18.11	Achieve intended use *(road construction)*
19	J5-Chbaniye-0	18.09	Priority Group 2 for Sorting, crushing and recycling
20	J4-Aaytat-0	17.91	Achieve intended use *(transform to a garden)*

4.4. GIS INTEGRATION

The same interface (Figure 4-3) created for running the Risk Sensitivity Index (RSI) can be used to automatically generate the preferred rehabilitation option its related costs for all dumps. The fact that all tabs are active is an indicator that the RSI has been calculated and that the model is ready to run the rehabilitation process and display the results.

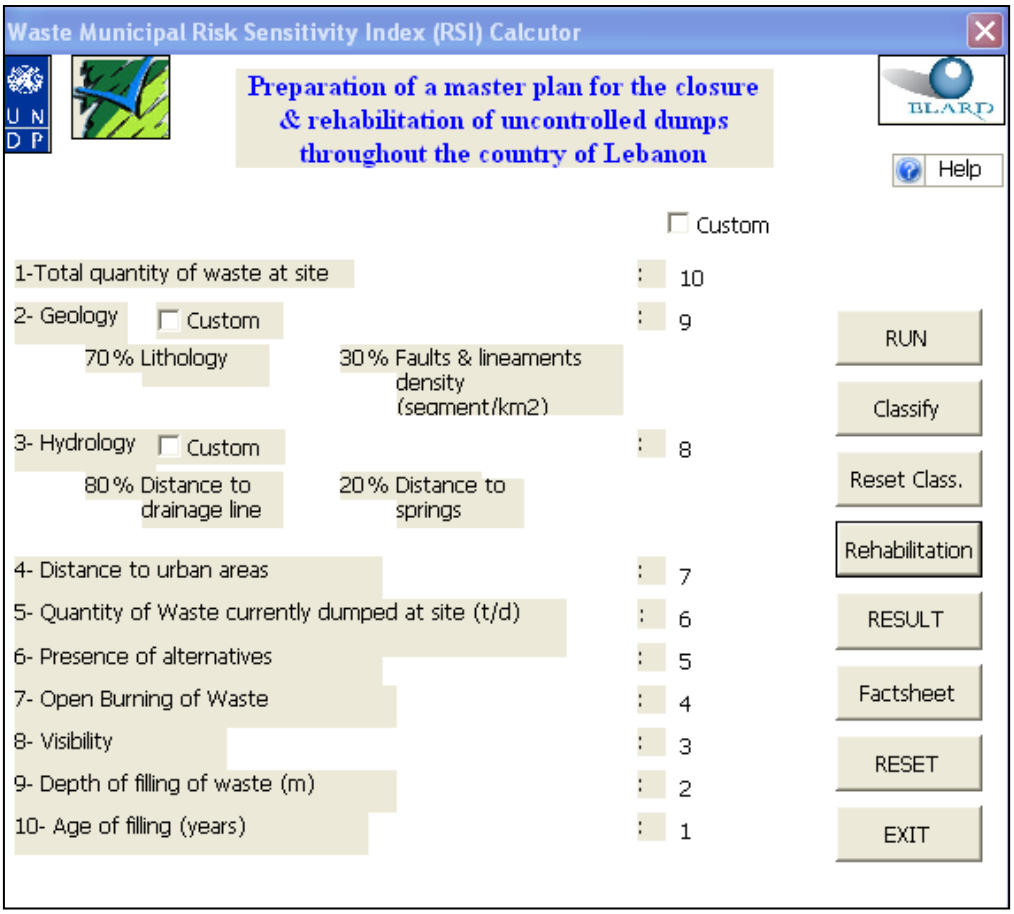


Figure 4-3 CDRSI Calculator Interface

The rehabilitation button in the designed interface applies the decision tree model using the IF…THEN….ELSE statement (Figure 4-4). When all statements are justified in the decision tree, the designed model automatically calculates the average cost ($/m3) and the total cost (US $) per dump depending on the rehabilitation type and the volume. These results are displayed in a standalone table (independent of the model) where the dump ID, its coordinates, the Caza and Mohafazat, the RSI score, rehabilitation type, average cost and total cost are displayed.

```
If pfeature.Value(ialternatives) >= 0.5 Then
pfeature.Value(irehabplan) = "Achieve intended use"
Else
  If pfeature.Value(ivolume) >= 50000 Then
    If pfeature.Value(ivisibility) >= 0.5 Then
pfeature.Value(irehabplan) = "Priority group 1 for Sorting, Crushing and recycling of C&D waste"
    Else
      If pfeature.Value(ivolume) >= 10000 And pfeature.Value(ivolume) <= 50000 And pfeature.Value(idistance) >= 0.5 And pfeature.Value(ihydrology) >= 0.494 Then
pfeature.Value(irehabplan) = "Priority Group 2 for sorting, Crushing and recycling of C&D waste"
        Else
          If pfeature.Value(istatus) >= 0.5 Then
            If pfeature.Value(ialternatives) >= 0.5 Then
pfeature.Value(irehabplan) = "Achieve intended use"
            Else
pfeature.Value(irehabplan) = "Transfer C&D waste to other priority dumps or to an approved C&D landfill"
            End If
          Else
pfeature.Value(irehabplan) = "Grade the surface and cover with soil (re-vegetate dump)"
          End If
        End If
    End If
```

Figure 4-4 VBA code for 3 loops in the C&D decision tree

5. ACTION FICHES

Once the models were run over all dumps, detailed rehabilitation Action Fiches were developed for the twenty top-priority dumps (20 highest ranking dumps) of each of the MSW and CDW dumps categories *(refer to section 3.2 on page 21 for further information on what these 20 priority dumps represent)*.

In addition to summarizing all dump characteristics, Action Fiches:

- List all technical, legal, monitoring, and operation and maintenance requirements for the implementation of the preferred rehabilitation option;
- Identify responsible parties;
- Estimate unit and average costs of implementation; and
- Identify possible sources for financing.

The 40 Action Fiches figure under Appendix C of this report. They detail the following, along with selected pictures:

13. Site name and location
14. Type of dump
15. Estimated volume of wastes (m^3)
16. Priority ranking for rehabilitation
17. Preferred rehabilitation option
18. Technical requirements (to be used as part of ToRs for contractor)
19. Responsibility
20. Legal requirements, if any
21. Monitoring requirements
22. Operation and maintenance requirements
23. Estimated cost
24. Possible sources of financing

Similar Action Fiches were generated for the remaining dumps (630); presenting the same information detailed above, with 3 variations:

- No pictures
- No technical requirements
- No <u>detailed</u> estimated cost

These Action Fiches also figure under Appendix C.

The designed GIS interface also contains an option that displays a printable version of all Action Fiches. Once the "Factsheet" button pressed, the user can either select a particular

dump and view/print its related Action Fiche, or export all to Excel sheets. The user can also open an overview window that shows the dump location on the map.

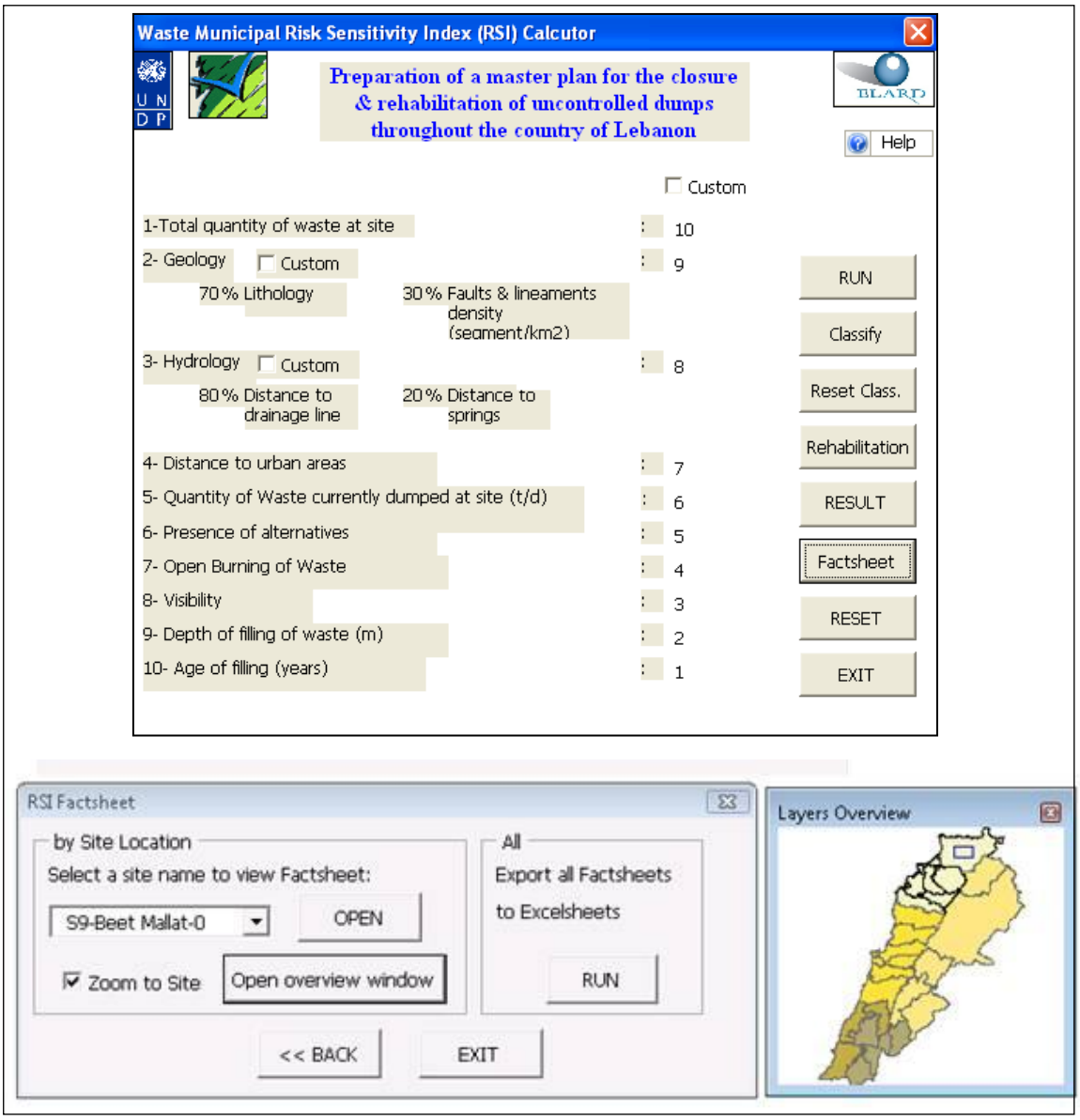


Figure 5-1 Action Fiches Interface

6. COST ESTIMATES SUMMARY

Unit and total cost estimates per dump for the 20 priority dumps are provided in Table 6-1 and Table 6-2; while Table 6-3, Table 6-4, Table 6-5, and Table 6-6 list total cost estimates per rehabilitation measure. Finally, Table 6-7summarizes total cost estimates for the rehabilitation of all MSW and CDW dumps.

Table 6-1 Summary of Cost Estimates for 20 MSW Priority Dumps

SITE NAME	REHABILITATION	VOLUME (m3)	AVG. COST ($/m3)	TOTAL ($)
Saida	Excavate, treat and transfer	1,200,000	21.11	25,335,600
C1-Deir Qanoun El Ain-01	Grade, Cap, Manage gases and leachate	183,450	3.88	712,501
N5-Hbaline-0	Grade, Cap, Manage gases and leachate	375,000	3.24	1,215,102
T9-Srar-0	Grade, Cap, Manage gases and leachate	150,000	4.04	606,165
R7-Adweh-0	Grade, Cap, Manage gases and leachate	150,000	4.42	663,483
E4-Kfartibnit-00	Grade, Cap, Manage gases and leachate	295,800	3.82	1,131,423
P5-Hamat-1	Grade, Cap, Manage gases and leachate	120,000	5.09	610,254
J7-Barr Elias-00	Option 1: Grade, Cap, Manage gases and leachate	120,000	3.82	458,630
	Option 2: In case of building a landfill in Barr Elias, Excavate and transfer waste to a sanitary landfill	120,000	5.17	620,000
M9-Baalbeck-2	Excavate, treat and transfer to sanitary landfill (not yet available but planned for 2012).	225,000	12.39	2,788,125
	Option 2: Direct transfer to sanitary landfill without volume reduction.	225,000	4.93	1,108,750
M9-Baalbeck-1	Grade, cap and manage gases	210,000	2.33	489,550
J6-Qabb Elias-00	Grade, Cap, Manage gases and leachate	140,000	5.03	704,644
G2-Ghaziyeh-00	Grade and cap and manage gases	102,300	4.31	441,231
S7-Maqaitaa-00	Option 1-Grade, Cap, Manage gases and Leachate	10,000	7.22	72,175
	Option 2-Group with other dumps and transfer waste (Adweh)	10,000	5.25	52,500
R9-Fnaydek-0	Grade, cap, Manage gases and leachate	60,000	5.70	342,250
J5-Rouayset El Ballout-0	Group with other dumps and transfer	5,000	5.95	29,750
L4-Zouk El Khrab-01	Option 1-Grade, cap, Manage gases and leachate	8500	6.70	56,988
	Option 2-Group with other dumps and transfer	8500	4.84	41,125
L8-Haouch El Refqa-00	Option 1-Grade, Cap, Manage gases and leachate	13,500	5.25	70,840
	Option 2-Group with other dumps and transfer	13,500	4.62	62,375
K7-Timnine-00	Group with other dumps and transfer (Baalbeck)	6000	4.75	28,500
R8-Birkayel-0	Grade, Cap, Manage gases and leachate	70200	4.60	322,609
P7_Beslouqit-2	Group with other dumps and transfer	3,000	5.25	15,750

Table 6-2 Summary of Cost Estimates for 20 CDW Priority Dumps

SITE NAME	REHABILITATION	VOLUME (m3)	AVG. COST ($/m3)	TOTAL ($)
L8-Chmestar-01	Achieve intended use (enlarge road)	225,000	0.36	81,200
I4-Ammiq El Chouf-0	Achieve intended use (transform to a garden and plant trees)	200,000	0.69	138,933
I4-Dmit-0	Priority Group 1 for Sorting, crushing and recycling	180,000	9.88	1,779,200
K4-Beit Meri	Priority Group 2 for Sorting, crushing and recycling	20,500	11.64	238,565
B3-Kounine-02	Achieve intended use (garden or playground)	8,580	6.64	56,964
L4-Mtayleb-1	Achieve intended use (building road)	15,000	2.13	32,017
K5-Mar Moussa Ed-Douar-0	Achieve intended use (agriculture)	30,000	3.37	101,100
L5-Ain Er-Rihane-3	Achieve intended use (road construction)	100,000	1.35	135,350
L5-Qlaiaat-3	Priority Group 1 for Sorting, crushing and recycling	75,000	9.36	702,000
L4-Zouk Al Khrab-2	Priority Group 2 for Sorting, crushing and recycling	30,000	9.36	280,800
L4-Dik Al-Mahdi-0	Priority Group 2 for Sorting, crushing and recycling	16,000	10.97	175,520
I5-Maaser Ach-Chouf-0	Achieve intended use (football court and parking)	18,000	2.31	41,600
E5-Chebaa-01	Priority Group 1 for Sorting, crushing and recycling	108,000	10.22	1,104,200
L4-Zouk Mosbeh-7	Achieve intended Use	2,000	8.13	16,267
Ia-Aatrine-1	Achieve intended use (annex to football court)	10000	5.31	53,100
L4-Zouk Al Khrab-4	Priority Group 2 for Sorting, crushing and recycling	14,000	10.39	145,440
L4-Zouk Al Khrab-3	Transfer to other priority dumps	42000	4.35	182,500
M5-Kfar Yassine-0	Achieve intended use (road construction)	4,500	3.10	13,950
J5-Chbaniye-0	Priority Group 2 for Sorting, crushing and recycling	10500	10.86	114,080
J4-Aytat-0	Achieve intended use (transform to a garden)	35,000	1.11	38,683

Table 6-3 Summary of Cost Estimates for 20 MSW Priority Dumps per Rehabilitation Plan

Grade, cap, manage gases and leachate

SITE NAME	VOLUME (m^3)	AVG. COST ($/m^3$)	DETAILS
N5-Hbaline-0	375,000	3.24	*Active venting, concrete intercepting channels*
E4-Kfartibnit-00	295,800	3.82	*Active venting, concrete intercepting channels*
C1-Deir Qanoun El Ain-01	183,450	3.88	*Active venting, concrete intercepting channels*
T9-Srar-0	150,000	4.04	*Active venting, concrete intercepting channels*
R7-Adweh-0	150,000	4.42	*Active venting, concrete intercepting channels*
J6-Qabb Elias-00	140,000	5.03	*Active venting, concrete intercepting channels*
P5-Hamat-1	120,000	5.09	*Active venting, concrete intercepting channels*
J7-Barr Elias-00	120,000	3.82	*Passive venting, concrete intercepting channels*
R8-Birkayel-0	70,200	4.60	*Passive venting, concrete intercepting channels*
R9-Fnaydek-0	60,000	5.70	*Passive venting, concrete intercepting channels*
L8-Haouch El Refqa-00	13,500	5.25	*Passive venting, concrete intercepting channels*
S7-Mqaitaa-00	10,000	7.22	*Passive venting, concrete intercepting channels*
L4-Zouk El Khrab-01	8,500	6.70	*Passive venting, concrete intercepting channels*

Grade, cap, manage gases and leachate

VOLUME	AVG COST ($/m^3$)
>100,000m3	4.0
between 10,000 and 100,000 m3	6.0
<10,000 m3	8.0

Grade, cap and manage gases

SITE NAME	VOLUME (m^3)	AVG. COST ($/m^3$)	DETAILS
M9-Baalbeck-1	210,000	2.33	*Passive venting, earth ditches*
G2-Ghaziyeh-00	102,300	4.31	*Active venting, earth ditches*

Grade, cap and manage gases

VOLUME	AVG COST ($/m^3$)
>100,000m3	3.0
between 10,000 and 100,000 m3	5.0
<10,000 m3	7.0

Excavate, treat and transfer to sanitary landfill with volume reduction

SITE NAME	VOLUME (m^3)	AVG. COST ($/m^3$)	DETAILS
G2-Saida-0	1,200,000	21.11	-
M9-Baalbeck-2	225,000	12.39	-

Excavate, treat and transfer

VOLUME	AVG COST ($/m^3$)
>100,000m3	10.0
between 10,000 and 100,000 m3	14.0
<10,000 m3	18.0

Transfer (without volume reduction) to other dump/sanitary landfill

SITE NAME	VOLUME (m^3)	AVG. COST ($/m^3$)	DETAILS
M9-Baalbeck-2	225,000	4.93	-
J7-Barr Elias-00	120,000	5.17	-
L8-Haouch El Refqa-00	13,500	4.62	-
S7-Mqaitaa-00	10,000	5.25	-
L4-Zouk El Khrab-01	8,500	4.84	-
K7-Timnine-00	6,000	4.75	-
J5-Rouayset El Ballout-0	5,000	5.95	-
P7-Beslouqit-2	3,000	5.25	-

Group and transfer to other dump/sanitary landfill

VOLUME	AVG COST ($/m^3$)
>100,000m3	4.0
between 10,000 and 100,000 m3	5.0
<10,000 m3	7.0

Table 6-4 Summary of Cost Estimates for 20 CDW Priority Dumps per Rehabilitation Plan

Achieve intended use

SITE NAME	VOLUME (m3)	AVG. COST ($/m3)	DETAILS *(INTENDED USE)*
L4-Zouk Mosbeh-7	2,000	8.13	-
K5-Mar Moussa Ed-Douar-0	30,000	3.37	*Agriculture*
Ia-Aatrine-1	10,000	5.31	*Annex to football court*
L4-Mtayleb-1	15,000	2.13	*Road construction*
L8-Chmestar-01	225,000	0.36	*Enlarge road*
I5-Maaser Ach-Chouf-0	18,000	2.31	*Football court and parking*
B3-Kounine-02	8,580	6.64	*Garden or playground*
L5-Ain Er-Rihane-3	100,000	1.35	*Road construction*
M5-Kfar Yassine-0	4,500	3.10	*Road construction*
I4-Ammiq El Chouf-0	200,000	0.69	*Garden + plant trees*
J4-Aytat-0	35,000	1.11	*Garden*

Achieve intended use

VOLUME (m3)	UNIT RATE ($/m3)
>100000m3	1
between 10000 and 100000m3	3
<10000 m3	5.5

Priority group 1 and 2 for sorting, crushing and recycling

SITE NAME	VOLUME (m3)	AVG. COST ($/m3)	DETAILS
I4-Dmit-0	180,000	9.88	*Priority group 1*
L5-Qlaiaat-3	75,000	9.36	*Priority group 1*
E5-Chebaa-01	108,000	10.22	*Priority group 1*
K4-Beit Meri	20,500	11.64	*Priority group 2*
L4-Zouk Al Khrab-2	30,000	9.36	*Priority group 2*
L4-Dik Al-Mahdi-0	16,000	10.97	*Priority group 2*
L4-Zouk Al Khrab-4	14,000	10.39	*Priority group 2*
J5-Chbaniye-0	10,500	10.86	*Priority group 2*

Priority group 1 and 2 for sorting, crushing and recycling

VOLUME (m3)	UNIT RATE ($/m3)
<20000 m3	11

Transfer to other priority dumps

SITE NAME	VOLUME (m3)	AVG. COST ($/m3)	DETAILS
L4-Zouk Al Khrab-3	42,000	4.35	-

Transfer to other priority dumps

VOLUME (m3)	UNIT RATE ($/m3)
<10,000 m3	5.5

Table 6-5 Summary of Cost Estimates for MSW Dumps per Rehabilitation Plan

REHABILITATION PLAN	VOLUME (m^3)	NUMBER OF DUMPS	UNIT COST	TOTAL VOLUME (m^3)	COST ($)
Grade, Cap, Manage gases and leachate	**-**	**33**	**-**	**2,287,220**	**8,770,684**
	>100,000m3	*9*	*4.0*		
	between 10,000 and 100,000 m3	*18*	*6.0*		
	<10,000 m3	*6*	*8.0*		
Grade, cap and manage gases	**-**	**23**	**-**	**683,371**	**2,886,948**
	>100,000m3	*2*	*3.0*		
	between 10,000 and 100,000 m3	*14*	*5.0*		
	<10,000 m3	*7*	*7.0*		
Excavate, treat and transfer	**-**	**1**	**-**	**1,200,000**	**25,335,600**
	>100,000m3	*1*	*10.0*		
	between 10,000 and 100,000 m3	*0*	*14.0*		
	<10,000 m3	*0*	*18.0*		
Group and transfer to other dump/sanitary landfill	**-**	**447**	*-*	**833,485**	**5,295,656**
	>100,000m3	*1*	*4.0*		
	between 10,000 and 100,000 m3	*0*	*5.0*		
	<10,000 m3	*446*	*7.0*		
TOTAL		**504**		**5,004,076**	**42,288,888**

Table 6-6 Summary of Cost Estimates for CDW Dumps per Rehabilitation Plan

REHABILITATION PLAN	*VOLUME (m^3)*	NUMBER OF DUMPS	*UNIT COST ($)*	TOTAL VOLUME (m^3)	TOTAL COST ($)
Achieve Intended Use	-	**43**	-	**725,596**	**1,227,045**
	>100000m3	*3*	*1*		
	between 10000 and 100000m3	*4*	*3*		
	<10000 m3	*36*	*5.5*		
Grade surface, cover with soil and re-vegetate	-	**25**	-	**120,437**	**331,273**
	between 10,000 m3 and 20000 m3	*6*	*3*		
	<10000 m3	*19*	*2*		
Priority Groups		**10**		**659,000**	**6,594,005**
	<20000 m3	*10*	*11*		
Transfer		**88**		**226,148**	**1,195,316**
	<10,000 m3	*88*	*5.5*		
TOTAL		**166**		**1,731,180**	**9,347,639**

Table 6-7 Summary of Total Estimated Costs

MSW DUMPS	**COST ($)**
Estimated cost of rehabilitating first 20 ranked dumps	34,313,942
Estimated cost of rehabilitating 504 MSW dumps	42,288,887
CDW DUMPS	**COST ($)**
Estimated cost of rehabilitating first 20 ranked dumps	5,560,552
Estimated cost of rehabilitating 166 CDW dumps	9,356,988
Total estimated cost of rehabilitating 670 open dumps	**51,645,875**

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8. APPENDICES

APPENDIX A – GIS PROJECT

(Please refer to enclosed CD)

APPENDIX B – PRIORITIZATION AND REHABILITATION RESULTS IN EXCEL FORMAT

(Please refer to enclosed CD)

APPENDIX C – ACTION FICHES

(Please also refer to enclosed CD)

APPENDIX D – HIGH-RESOLUTION MAPS

(Please refer to enclosed CD)

APPENDIX E – MOBILE CRUSHER BUDGET REQUIREMENTS

Capital Costs

Mobile crusher	350,000 euros
Additional screening unit	100,000 euros
Spare parts for (2 years)	150,000 euros
TOTAL	**600,000 euros**

Operation and Maintenance costs

- ✓ Depreciation of the equipment
- ✓ Fuel, consumables
- ✓ Wear and tear
- ✓ Personnel

O&M/year: Around	**200,000**	euros/year
	~288000	$

Rate	100	t/hr
Working hours / day	8	
Total capacity /day	800	
Total capacity/year	240000	t/yr
	282352.9	m3/yr
Cost of O&M of mobile crusher	1.02	$/m3
Dump	200000	m3

	Unit	Quantity	Unit price (US$)	Total price (US$)
Front end loader	m3	200000	3	600000
Jack hammer	m3	60000	4	240000
sorting personnelx2	months	8.5	1200	10200
Screening trommel	m3	190000	4	760000
Mobile crusher	m3	80000	1.02	81600
Transfer trucks	truck	5000	50	250000

Revenues

Aggregate (coarse, medium, fine)	m3	60000	6	360000
Sand & fines	m3	60000	1.5	90000
Recyclables (wood, plastics, etc)			20	
Steel	t		25	

APPENDIX F – PRESENTATIONS

(Please refer to enclosed CD)