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Irrigation Improvement Projects in the Nile Delta

Promises, challenges, surprises

François Molle, Edwin Rap, Doaa Ezzat Al-Agha, Ahmed Ismail, Waleed Abou El Hassan and Mohammed Freeg

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Water and salt management in the Nile Delta: Report No. 4

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tertiary canal

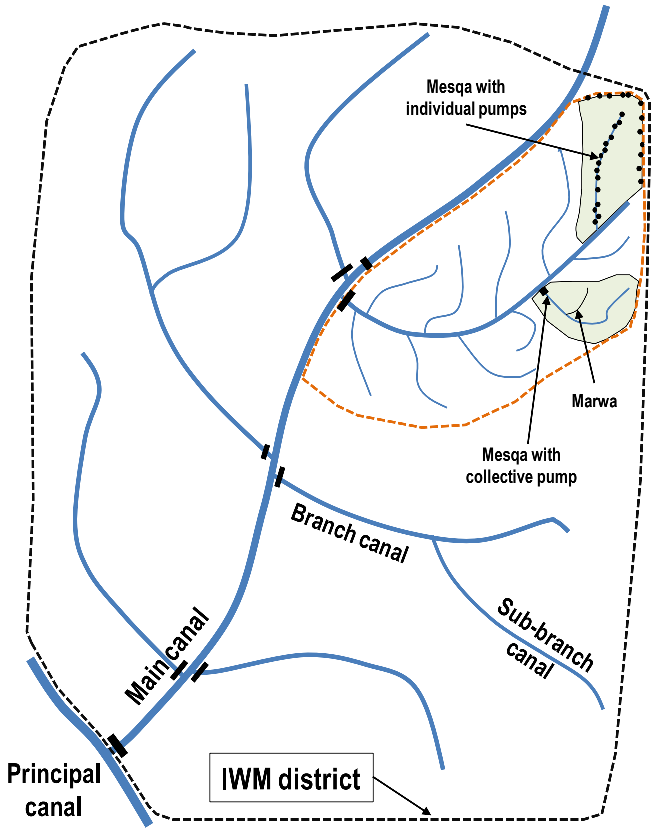
1 Introduction

1.1 Context of the study

In the world of irrigation the Nile Delta sticks out as a remarkable case because of its size (over 2,000,000 irrigated hectares) and the complexity of its distribution network. This network is comprised of 20,000 kilometers of canals of different dimensions, and is paralleled by an equally ramified drainage network. The structure of the distribution network has been expanded and considerably adapted and modified during the long history of agriculture in the Delta. As a result there is considerable connectivity between waterways at all levels, including canals and drains, let alone the numerous pump stations that supplement some canals with the water from main/secondary drains, or maintain water levels in drains low enough for them to function as planned (see IWMI-WMRI report No. 1, 2013).

The conventional structure of the distribution systems involve successive levels, from main feeders (rayah) to main (primary) canals, branch canals (secondary), *mesqa* (tertiary) and *marwa* (quaternary field ditches). But this structure is not always so straightforward, because branch canals may fork out and have subbranches; others may be quite small (serving for example 500 feddans), shorter than some mesqas, which may be several kilometers in length and serve over 1000 feddan). But the name also reflects the legal status of the canal: branch canals are public property, and there is a right of way to be respected along them, while mesqas are located on private land and owned and maintained by farmers.

Figure 1. Management levels in Egyptian irrigation (delta)



Mesqa
5-60 ha
< 100 farmers

Branch canal
400-3000 ha
1000-10,000 farmers
< 15 villages

IWM district
8000-25,000 ha
40,000-100,000 farmers
~12 branch canals
30-100 villages

Governorate
200,000-500,000 ha
>1,000,000 farmers
>500 villages

The circulation of water across such a wide network is somewhat mind-boggling. Main channels, down to the inlet of the mesqas, are managed by the Ministry of Irrigation and Water Resources through several nested administrative units (the irrigation distribution service at the ministry level; the governorates; the inspectorate; and the district). Managers have to deal with the uncertainty of both supply (the inflow into their canal depends on upstream conditions) and demand (what are the farmers actually cultivating and how much water they are abstracting or willing to abstract). They also have to contend with physical infrastructures that are not stable: canals are subject to siltation, sliding of embankments, growth of weeds, waste disposal, etc. and need to be dredged and weeded once or twice a year. Their hydraulic characteristics are therefore changing.

Three main interlinked conventional issues in an irrigation system are its overall efficiency (how much water has to be distributed at the head of key canals to meet given requirements), the equity of distribution (making sure that water is evenly distributed within these canals), and timing (water is eventually available at the right moment at the right place). Meeting these objectives is therefore predicated upon a sound understanding of how water is managed and distributed both upstream (the ministry) and downstream (individuals or groups of farmers) of the mesqa inlet, and of the interface/coordination between the two levels.

In Egypt, water is traditionally distributed between branch canals according to a rotation system generally described as having two turns in summer and three in winter: this means, typically, that a canal will be 5 days 'on' and 5 days 'off' in summer, and 5 days 'on' and 10 days 'off' in winter. The number of days 'on' is normally calculated based on the capacity of the canal and its estimated aggregated water requirement. The central task, but also difficulty, of water management is to ensure the predictability of this rotation and also the adequacy of the discharge that is delivered during the 'on' period. Uncertainty in timing and availability in terms of quantity not only results in mismatch between supply and demand but also in risk-minimizing strategies on the part of the farmers. If water supply is uncertain it becomes logical to store it, and the only is reservoir available to farmers is the soil profile. Consequently farmers tend to over-irrigate when water is available to them, which results in higher losses in these farms and in depriving farmers located further downstream on the branch canal from their water. Unpredictable water supply, although partly mitigated by the possibility for some farmers to abstract water from the drains or the aquifer, results in sub-optimal irrigation of the crops and losses in yields and income and hinders farmers from adopting more valuable cash crops (which demand more cash investments that would be at risk).

Pondering about these issues in the 1970s, irrigation specialists and managers have attempted to come up with different technological and institutional improvements. Numerous experiments were in particular conducted by the seven-year Egypt - Water Use and Management Project (EWUP, 1977-84), an interdisciplinary research project implemented by the Ministry of Water Resources and Irrigation (MWRI) and researchers from Colorado State University. Out of the recommendations of that project, two major and complementary items were picked up and tested, before maturing into a series of successive 'irrigation improvement projects':

- A technological solution to the vexing issue of stabilizing supply into (secondary) branch canals: the use of 'distributors' at the head of the canal, that is, baffle regulators that allow managers to determine and fix the discharge to the Branch canal. This was later completed with 'downstream control regulation', that is, automatic gates that react to a drop of water level in the branch canal (due to farmers' abstraction) by opening and allowing more water in. The objective is to establish *continuous flow* in the canal, as opposed to a rotational system, while delivering the same amount of water on the whole.

- The establishment of *collective* pump stations serving buried piped distribution networks (and initially sometimes elevated lined canals) to deliver water at the tertiary (*mesqa*) level, as a substitute for a situation characterized by diffuse *individual* pumping from multiple points (canals and drains). This would result into economies of scale, better equity among farmers of the same mesqa, increased efficiency through better distribution, and in minimizing use of drainage water (with its salinity and quality problems).

Implementing the ideas of continuous flow and collectively managed mesqa-level pump stations in the delta is nearing thirty years of history. They were first encapsulated in the Irrigation Improvement Project (IIP), launched in 1987 and supported by USAID, turned into a full-fledged program in 1989, expanded by a World Bank/KfW-funded project in 1995, and later in 2006 -and up to these days- expanded into the Integrated Irrigation Improvement and Management Project (IIIMP).

This intervention has been praised as spearheading the "modernization" of irrigation in Egypt, the IIP being "a state-of-the-art project, especially in terms of the approach followed in involving the end users - the farmers - through Water User Associations (WUAs) in the design, implementation and maintenance of the physical structures and the allocation and distribution of water by WUAs themselves" (Hvidt, 2005); "The IIP is to be seen as the first step to bring the Egyptian irrigation system in line with the functional demands it will be facing by the turn of the 21st century" (Hvidt, 1998). In 2007 the project had improved 2900 mesqas covering an area of 200,000 feddan (World Bank, 2007). To this achievement must be added 36,000 feddan of irrigated area equipped with collective pumps by IIP2 (funded by KfW), 52,000 feddan (with a target of 85,000 in 2016) improved by IIIMP until 2014, with 494 WUAs considered as operational (World Bank, 2014), as well as areas improved by the Irrigation Improvement Sector (IIS) with national budget.

According to World Bank (1994), the overall objectives of the IIP project were to: "(a) increase agricultural production and farmers income by improving the irrigation infrastructure, facilitating a more equitable distribution of water, and improved on-farm water management; (b) improve the long-term sustainability, through takeover of responsibility for the operation and maintenance of the tertiary level irrigation system by the farmers and their sharing in the costs for the tertiary level investments; and (c) strengthen the institutional planning and implementation capacity of MPWWR in the irrigation subsector."

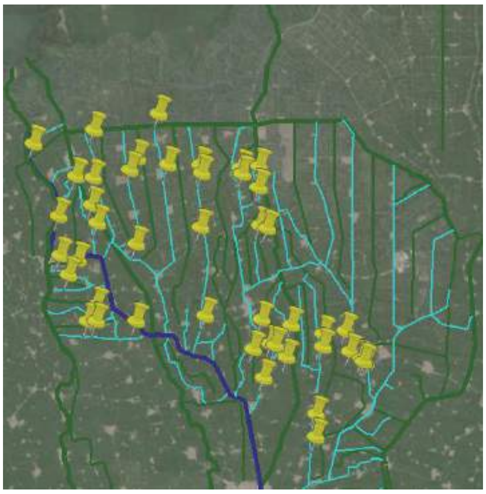
The Irrigation Improvement Sector (IIS) of the ministry, which is in charge of the supervision of all the projects and investments related to the introduction of collective pumps and associated changes, has the mandate to generalize these investments to the old lands of Egypt. As a result reporting information on how these socio-technical innovations perform on the ground, how they change water distribution and how they are in return adopted and reshaped by farmers, is of great importance. Understanding in which context improvement projects are most beneficial and successful and, on the other hand, in which conditions these investments might be at risk should lead to recommendations on how to improve the design and implementation of these projects.

This report presents a number of observations and findings derived from several fieldwork activities carried out in the Meet Yazid canal command area between January 2013 and January 2015.

1.2 Methodology

The present report is based on several sets of observations collected during different field surveys. The core survey included a sample of 49 pump stations (PS), that included stations from both IIP (23) and IIIMP (16) projects, as well as distribution networks through both earthen (no improvement) and piped marwas. The majority of the stations were distributing water through a main pipe (44), but four of them used an elevated concrete canal. During the course of this survey, which took place between October 2013 and January 2014, a number of additional casual observations on other PS were also made. The PS were selected randomly – a main criteria was the presence of farmers nearby, so that the questionnaire could be applied – while making sure that the sample would be spread over the whole area equipped with collective pumps, with a more or less balanced distribution between the upstream and downstream sections of each branch canal.

Figure 1. The 49 surveyed Pump Stations distributed over Meet Yazid



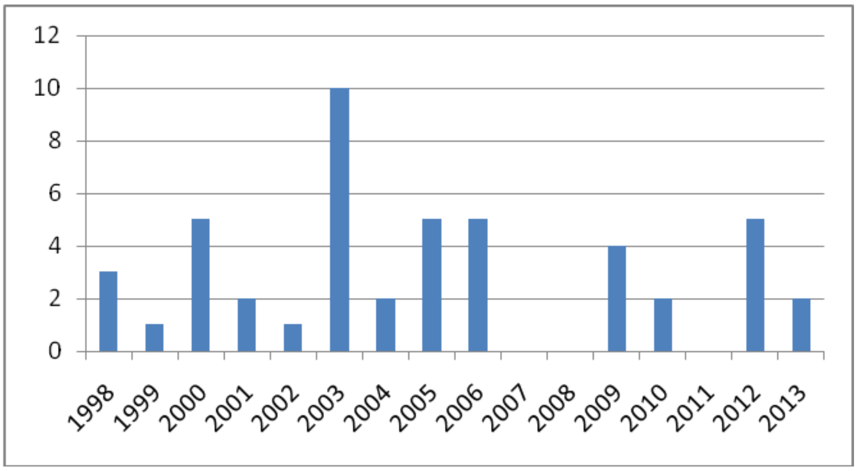
This report also makes use of the many observations gathered during the exploratory survey conducted during the first semester of 2013 and already analyzed in IWMI-WMRI report No. 1 (2013). Additional information is also drawn from two in-depth case studies that have been carried out in 2013-2014 in the W10 area and in the Abu Mustafa branch canal area, where two pump stations in each location have been monitored in detail during one year, as well as from Mares El Gamal canal area, where a water balance is being conducted in an area that includes 12 IIIMP pump stations (see IWMI-WMRI report No. 5, '*Irrigation Water use at the meso-level in IIIMP areas, Mares El Gamal canal*').

While conducting the core survey it became clear that our methodology was biased because of three reasons:

- We mainly circulated on the roads located on the embankments of the branch canals, and therefore missed out some pump stations located along, or at the end, of sub-branches and long mesqas.
- The questionnaire was designed to investigate the actual operation and maintenance of collective pump stations; we of course disregarded all the stations that were not being used, or which were empty.
- Some of the IIP pump stations were old (15 years), while all IIIMP pumps had only been recently constructed.
- These facts were introducing a positive bias since the stations *not* located along the branch canals are expected, on average, to face a less favorable access to water. And of course, disregarding the nonfunctioning pump stations would prevent us from gaining insight on the percentage of such cases, as well as on the reasons for their being abandoned. The difference in dates also meant that the cases were not fully comparable, since pump stations

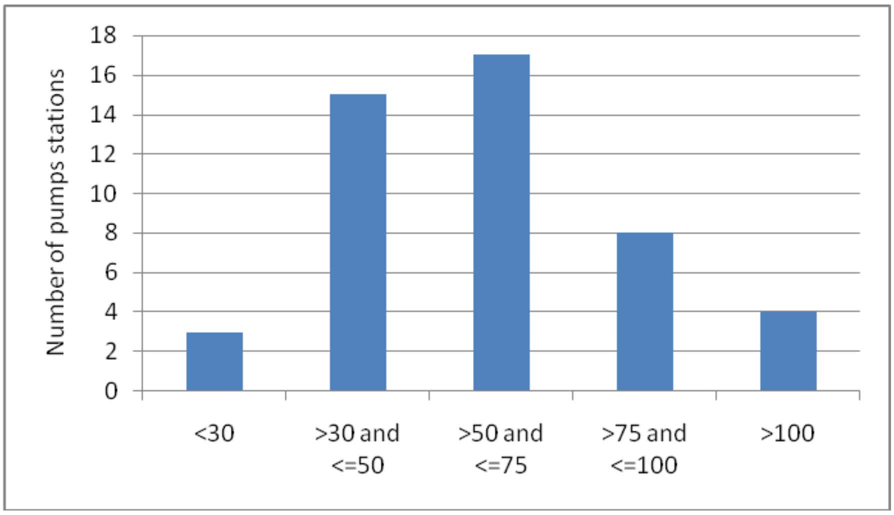
established 10-15 years ago have generally gone through various changes, unlike those that have been set up in the past two years. We only considered stations with at least one full summer season of functioning.

Figure 2. Distribution of the sample according to the date of construction of the PS



Because the size of the area served by one pump station may vary a lot, and because this variable has a significant bearing on a number of issues, we have tried as much as possible to consider small as well as big stations (Figure 3).

Figure 3. Distribution of the sample according to the size of the command area (fed)



To overcome some of these biases, the research team also undertook a global survey among a large number of PS. We designed a *short* list of observation items, meant to be filled in for *all* stations, with a few additional questions in case a farmer would be available near the station, especially for stations that were found to be in disuse. These items mostly concerned the number and type of pumps (diesel and electricity), whether the hardware had been modified with regard to the initial equipment, the presence of individual pumps, etc. The questions focused on whether there had been changes in the area served, if the motors had been stolen, and what were the reasons for the station to be abandoned. Researchers and technicians visited the equipped area in a more or less systematic way in order to take geo-referenced pictures of all the pump stations. A portion of these could not be documented for lack of nearby informant at the time of the visit. By doing so we also slightly underestimated the number of nonfunctioning stations because some of those which, on visual observation, were equipped with their pumps may have in reality been in disuse (as we did observe a number of such cases). In total, this large 'global survey' collected information on 640 pumps out of a total of around 1000.

2 Irrigation Improvements' design and promises

2.1 The IIP concept

As indicated above the, the overall objectives of the IIP project (World Bank 1994) were to increase agricultural production and farmers income by improving the irrigation infrastructure, facilitating a more equitable distribution of water, and improved on-farm water management, while entrusting Water users associations with O&M responsibilities.

As stated above, the IIP concept has evolved with time, from its first phase under USAID funding, the second phase under World Bank-KfW support, and the more recent IIIMP. The main tenets of the concept are 1) the establishment of continuous flow in secondary canals, mediated through automatic downstream control gates and baffle regulators at the head; 2) the replacement of diffuse individual pumping by collective pumps at the tertiary level, with corresponding mesqas being filled in; 3) the distribution of water through a buried pipe network and valves; 4) the establishment of Water User Associations at the mesqa level (pump station WUAs), and at the branch canal level (BCWUAs); 5) additional and optional extension of the distribution network down to the plot level by piping marwas (field ditches). Projects included also various components of capacity building and institutional development at the level of the ministry. The technology would also bring about several benefits in terms of ease in use, as described below.

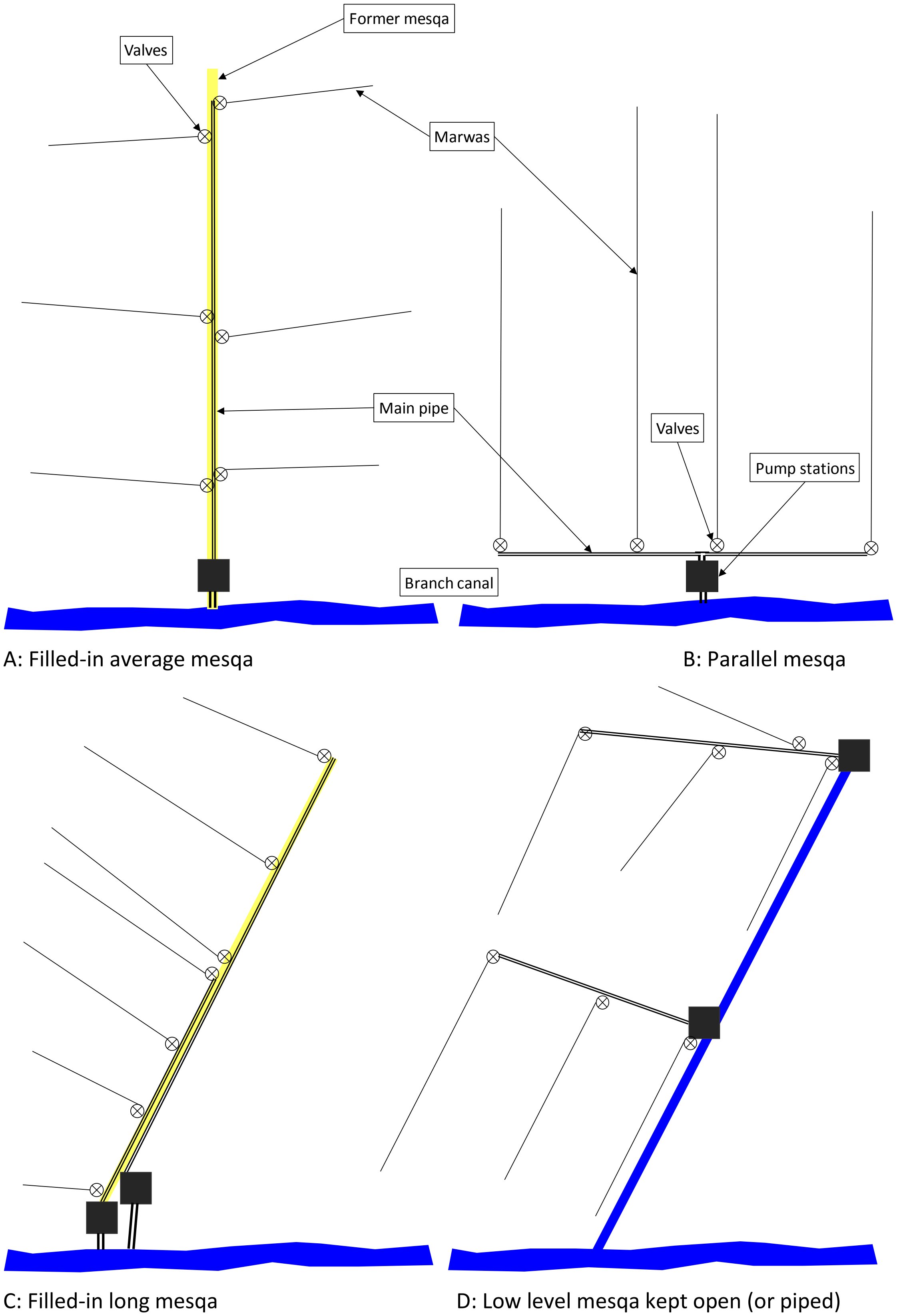
The two major changes for farmers obviously were the promise of continuous flow, which sounded as the end of their woes, and the replacement of their individual pumps (IPs) by collective pump stations (PS). A major question is how farmers are to be grouped together since not all farmers pump from a tertiary canal, and since these tertiary canals may differ markedly.

Figure 4 presents several configurations of design which depend on site characteristics. Their differences have crucial implications in terms of technical characteristics, but also in terms of constitution of social groups of users. In situation A, the mesqa is filled in and replaced by a distribution pipe, usually buried alongside the (former) mesqa ditch. Valves are placed at different locations, often where before a sakia or later the lifting points for individual pumps were located, to serve one (or several) marwas. This is the standard situation, where the pump is managed by the same farmers who previously used to abstract water from the same mesqa.

In situation B, farmers used to abstract water directly from the branch canal (there is no mesqa) and the distribution pipe is therefore placed parallel to the canal, with each valve serving an existing marwa (and replacing, or in most cases overlapping with, the nearby set of individual pumps that were serving this marwa). This situation is referred to as '*parallel mesqa*'. In principle, existing bays (pump sumps) from which a group of pumps was extracting water should be filled in and removed.

In situation C, the former mesqa is too long and its command area is too large to be served by one single pump station: a solution is therefore to design two pump stations located on the branch canal and serving the first and the second half or the left and the right part of the command area respectively. In situation D, this is not possible because the area is too large, so the mesqa ('*low-level mesqa*') is left open and pump stations are constructed along its course. The mesqa acts almost as a sub-branch and may need to have its capacity upgraded in line with the capacity of the pumps. In some cases, especially for long mesqas like at the Halafi canal, it is piped, although this comes at an additional cost to farmers.

Figure 4. Different types of configurations for collective pumps



2.2 Expected benefits

The IIP package was potentially very attractive and had several expected benefits (Hvidt, 1994; Lowdermilk and Barakat, n. d.; APRP, 1998):

- The collective pump stations would do away with the scattered and diffuse individual pumps and achieve economies of scale in terms of energy costs for both farmers and society (See Sections 5.4 and 5.5).
- Engineers anticipated that continuous flow would put an end to unpredictable supply, which was considered as the main cause of farmers' "over-pumping" during their 'on' turn (seen as a means of storing water in the soil profile to offset possible discontinuities in supply). (Section 3.1).
- Delivery of water to the marwa or plot level through a network of lined canals or pipes would reduce losses and improve irrigation efficiencies (also limiting overall water abstraction and return flows to drains, where quality is often degraded).
- Equity of water distribution would be improved due to the ease in distributing water and head-end/tail-end inequities would be relieved (Section 5.2).
- Positive environmental and health impacts would result from farmers no longer needing to pump polluted and/or saline drain water and mesqa being filled in (Section 5.4).
- Filling-in mesqas would increase arable land by 1 to 2% (Section 5.6).
- Farmer's irrigation costs (labor, pumping and mesqa maintenance) and burden (necessity to move the pump back and forth) would be substantially reduced (Sections 5.3 and 5.5).
- Increased crop yield, diversification to cash crops (and farmer income) would result from a better and more secure availability of water, especially for downstream plots (Section 5.1).

All these benefits were estimated mostly based on pilot projects in Upper Egypt during the EWUP research project (1977-1984) and the IIP-USAID phase in the early 90s. These assessments were used as a basis for the calculation of the internal rate of return of the IIP-USAID phase. Likewise, later experiments with on-farm development in the W10 area by the GTZ would yield economic parameters used by the World Bank for the design of the IIIMP project.

2.3 Performance assessed in earlier studies

A number of assessments and studies have been carried out during the lifetime of this project. Some of these studies have attempted to quantify the benefits observed on the ground and have concluded that the project was by and large meeting expectations (Hvidt, 1996). Other studies, including a long-term monitoring and evaluation of the implementation of the pump stations carried out by Egyptian research institutes have (WMRI, 2006), on the other hand, found that many of their results were inconclusive, because –among other things– of the difficulty to measure them on the ground and to separate the different causal factors.

2.3.1 Introduction of continuous flow operations

The establishment of continuous flow, "the key and lead technology of IIP" (IRG et al., 1998), has been the main challenge. "The mesqa improvements of IIP lack meaning and are not technically and economically feasible without continuous flow" (IRG et al., 1998)[1]. Many mesqas were equipped with pumps before the interventions on the branch canals (remodeling of the canal) were completed (or sometimes initiated). As a result, continuous flow could not yet be implemented, frustrating farmers

[1] For a review of the advantages and disadvantages of continuous flow, see MottMcDonald and Sabbour, 2008.

for whom this was the most attractive promise (IRG et al., 1998). The lack of branch canal profiling and other technical reasons made it necessary to ensure preferential allocation to IIP canals, which affected the balance with other canals and drew complaints from them (Hvidt, 1998). The recommendation was therefore made that continuous flow should be operationalized in the command area prior to improved mesqas coming on line. The BCWUAs could be formed early on, assist in the works on the branch canals, and then later on help in setting up the WUAs at the mesqa level (IRG et al., 1998). These expectations could not be met, because continuous flow could not be implemented during the IIP project. In 2007, the World Bank (2007) cautiously avoids questioning whether this could ever happen, and what would be the implications if the answer to this question was 'no'. It notes that "the establishment of CF regime operations will require a more complex process than was originally appreciated, and more time and greater effort will be needed to achieve this".

The call for implementing continuous flow was repeated along the years in seminars and documents. In 2010, for example, the IIIMP, in cooperation with the Egyptian-Dutch consultation panel (APP), announced that it would "pilot the application of continuous flow (CF) in four branch canals in order to understand the real constraints that prohibited its implementation and to come up with recommendations in order to enable applying it successfully as originally planned" (APP, 2010).

For reasons briefly discussed elsewhere (IWMI-WMRI report No. 1, 2013), continuous flow could not be established to this date and most people believe this is unlikely to happen soon or ever. The 120 or so automatic gates installed in the 'improved areas' are currently in disuse.

2.3.2 Changes in water abstraction

Hvidt (1998) analyzed results based on the monitoring of 27 mesqas in Upper Egypt by the IIP monitoring program during the 1993 summer season and found that adequacy of water supply and reliability had been improved, while night irrigation events had been reduced by 87%.

The monitoring and evaluation of the IIP project (WMRI, 2009) was not able to evidence changes in water consumption or in crop productivity. According to the final report, "the statistical results showed that there was no significant different between water supply values at the head of improved and unimproved canals (…) [and] no confirmation about the achievement of the improvement targets. As a result, most of the reports in this program concluded that the results are affected by the characteristics of the investigated canals more than being affected by their improvement state".

Indeed, as discussed elsewhere (IWMI-WMRI report No. 1, 2013), the issue of estimating whether farmers and canals provided with IIP pump stations have been abstracting more or less water than before (and therefore whether they have saved water) is irrelevant if continuous flow is not implemented. Indeed continuous flow was supposed to remove uncertainty in supply and therefore change farmers' irrigation practices have not been forthcoming. In addition, 1) estimating the actual use of water by farmers is made difficult by the continued use of numerous individual pumps, 2) there is no particular knowledge on how much water farmers were abstracting before IIP. Farmers' abstraction of water is first and foremost dependent upon how many days water is available in front of their field intake, and given the absence of CF chiefly relates to branch canal water management in general, and in how rotations are implemented in particular.

It is also worth reminding that although the project has sometimes claimed to be resulting in water savings, other analysts have stressed that if "IIP has resulted in more fresh water being available in improved areas [...], it is important to note that planned irrigation department water deliveries have not been increased, rather they are better controlled and distributed, and operational losses directly to drains are eliminated (IRG et al., 1998). In other words, branch canals are expected to receive the same amount of water as before with gains coming from a more equitable distribution within these branch canals, with benefits in terms of equity and productivity at the end of the canal.

The completion report of the IIP project acknowledges that: "It was difficult to assess the impact of the IIP on goals such as water savings since it will take some time to complete application of CF operation and for its impact to materialize" (World Bank, 2007). Yet "based on the theoretical requirements and on the overall irrigation efficiency improvement as presented above, ... potential water savings resulting from these assumptions were estimated to be up to 27.8 % in the with-project situation".

2.3.3 Changes in yields and other economic parameters

Yield improvements are always very difficult to document, not only because they vary each year based on a high number of parameters, but because it is very hard to trace causal links between specific parameters and productivity. The same can be said about changes in cropping patterns.

Hvidt (1998) refers to IAS data given for one area with increasing yields of 16% for maize, 11% for cotton, up to 18% for rice, but does not elaborate on how increases in income due to purported increases in yields have been calculated. A later evaluation study concluded that "statistically-based conclusions supporting or rejecting hypothesis of positive and negative IIP yield impact cannot be drawn due to data variability, the small sample size and the fact that data from only one season were being compared"](IRG et al., 1998).

In the appraisal document of the IIIMP project: "The expected establishment of continuous (on-demand) water flow in branch canals and mesqas, together with the on-farm investments and activities like marwa improvement and on-farm water management, will allow water savings of 27% while at the same time permit crops to be irrigated more efficiently"; yields were still expected to "grow gradually during 5 years, increasing from 4% to 25% depending on crop and location" (World Bank, 2005).

While changes in terms of water savings and increase in yields are hard to identify, other economic parameters have been easier to monitor. It has been a quite consensual observation that pumping costs have decreased as a result of the implementation of the improvement projects (by 34% according to World Bank, 2007), as is the time spent to irrigate. Hvidt (1988) however reports annual pumping costs for an average farm of 343 and 672 EGP for farmers owning and hiring individual pumps, respectively, while the cost after improvement is estimated at 429 EGP. He found the time taken to irrigate one feddan to decrease between 42% (wheat and maize) to 61% (berseem).

2.4 Implementation problems identified in earlier studies

The evidence available is mainly derived from the Monitoring and Evaluation components (carried out by the ministry itself), evaluation reports by IRG et al. (1998), MottMcDonald and Sabbour (2008) or the World Bank (2005, 2007), as well as a few occasional local studies.

2.4.1 Overall project support

The rate of implementation has been slower than expected. IIP and IAS (Irrigation Advisory Service) staff were insufficient or overburdened with additional tasks (IRG, 1998a). Both World Bank-funded IIP and USAID IIP projects were hindered by staff turnover and losses of trained personnel, "lack of adequate training, lack of career opportunities and low salaries unattractive to new engineers, lack of support for field staff, and other internal management problems" (IRG, 1998a).

2.4.2 Cost Escalation

During the implementation of the project it became apparent that the cost of IIP works for mesqa rehabilitation was escalating and becoming excessive. This had several causes (WB, 2005), including delays in completing works; the tendency to overdesign pumps and pipelines under the expectation that continuous flow would not happen (with the same amount of water needing to be distributed during the shorter period of 'on' days); higher than expected costs for contractors and tasks like filling up of mesqa, unmet expectations that more private sector participation in contracting would reduce costs; and devaluation of the currency.

The IIIMP economic and financial studies have shown that such high costs would threaten the project's economic feasibility and also lessen the financial attractiveness of the package for farmers (WB, 2005). Several cost-cutting technical adaptations were tested in an experimental area called W-10 and integrated into the IIIMP proposal before it started, including a switch to electrical pumps, a change in valves, a reduction of the pump capacity and of the diameter of pipes.

2.4.3 Construction quality

Contracting procedures and contractor performance have remained a strong concern up to present. "Contractor non-performance not only caused project delays but seriously undermined farmer confidence in the IIP and its abilities" (IRG, 1998). Non-performance includes poor work execution (canals with faulty slope, leaks in canals or pipes, bad compacting, poor design and too low pressure in pipes, etc.), low or no responsiveness to the problems signaled by farmers after construction, etc. The limited monitoring of work and accountability created situations where contractors were rushing to bid for and initiate new works without having finished the on-going ones (in some cases, re-contracting of a new firm has been necessary). Contractors' performance and reducing implementation delays was reportedly improved through consideration of smaller contract packages (World Bank, 2007). These problems of low quality work are actually observed in all types of interventions (e.g. canal dredging) and seems to either receive insufficient attention from officials or to be very resilient to change.

2.4.4 Maintenance and sustainability

One of the most nagging problems invariably reported by farmers is the difficulty to find spare parts or to find the technical expertise to address technical problems. This is true for all kind of pumps, including electric ones and associated transformers. This was true in former phases of Improvement Projects and remains so, as made explicit in section 5.

2.5 The next step: the IIIMP

The IIP project has been briefly presented above through its mains features (filling-in of mesqas, collective pump stations, and continuous flow in branch canals). In 2006, the Integrated Irrigation Improvement and Management Project (IIIMP) project, funded by the World Bank, KfW and AFD, was launched as a successor project of IIP.

The IIIMP adapted and developed the technological package of IIP, introducing some adjustments already tested in IIP2 or W10. The main changes were: electrical rather than diesel pumps, a separate electricity grid, reduced pumping capacity, cheaper piped distribution lines, the option of on-farm/marwa-level improvement, and the *de facto* abandonment of continuous flow in branch canals (Table 1). This new project also takes a much broader approach than the IIP by also considering the establishment of WUAs, BCWUAs and more widely integrating users participation, decentralization, IWRM, institutional reform and system modernization into a "From Mesqa to District" approach (APP, 2007; World Bank, 2005). In addition, the project enables a number of additions to the IIP package in areas in which IIP has been implemented earlier.

The project has been under way for a shorter period than IIP and has experienced setbacks due to the Revolution of 2011. The project execution has suffered and the project therefore received an extension in 2013 of 2 years, with termination expected in June 2016. Because of this delay in implementation a limited number of pump stations were working at the time of the survey and it was therefore difficult to assess the overall impact of the project interventions in MYC area up to present. Although a number of observations can be made about the current status of the technological improvements and the organizational and institutional interventions, which are often associated with each other, most of the observations that follow relate to IIP.

Table 1. Comparison of design criteria between IIP and IIIMP.

Design Criteria	IIP1	IIIMP
Design water duty	Design at maximum crop water requirement of 100% rice The operation hours is 16 hour Water duty = maximum peak monthly crop water requirement 1.15 l/sec/feddan (40m3/fed/day)	Design at maximum crop water requirement of 100% rice crop cultivated Taking the effective pump operating hours is 20 hours The crop water duty equals 0.84 l/sec/feddan (32 m^3/feddan/day)
Planning criteria	Minimum flow rate of turnout is 30l/sec Mesqa with area served less than 20 feddan is consider a marwa Design discharge for mesqa must be multiples of 60.	Maximum area served by mesqa is 120 feddan Very small or very large mesqas should be avoided, the preferred size range is between 50 and 100 fed and minimum area is 15 feddan and minimum preferred area served is 24 feddan Outlet area served min. 4 fedd. and max. 16 fed.
Pipeline system	The design pipelines are PVC 0.5 bar (maximum head 5m). Alfa-alfa valves are used with discharge 62 l/sec for minimum operating head 30cm and the diameter is 25cm When calculating pipelines losses the last reach of the pipe should be assumed with discharge 60l/sec Minimum Pipelines diameter was 315mm and the maximum was 500mm. Minimum pipeline length is 250m A stand was used and the maximum water level was 5m. Air vent should be provided at the end of each branch. Allowable velocity from 0.5 to 1 (0.8 l/sec)m/sec	Used pressure pipe is 4 bar operating head Used fittings are of 10 bars operating head the pipes used are PVC pipes of 180,200,250,280,315,355 and 400 mm diameter for the pipelines the minimum used diameter is 200 mm except for one pumping unit, where 180 mm dia. Pipes could be used the riser should be 160 mm diameter and 20l/sec discharge capacity the gate valve of 150 mm inner diameter is the mesqa intake in case of using stand, the pipeline to be provided with open air vent at the tail end of each branch in case of direct pumping, the pipeline to be provided with air vacuum valve on the pump manifold. Also a pressure relief valve is installed at the pipeline end earth cover should be 0.8-1.20 m maximum allowable velocity in pipes 1.6 m/sec Energy used is the electricity
Pump selection	Maximum number of pumping units to be 3-units in pump houses	Maximum number of pumping units to be 3-units One pumping unit can be used in small served area

	Minimum number 2 (avoiding reliance on one pump only and providing for a standby one) Design pump capacities are 60, 90 and 150 l/sec	within 15 feddan Nominal pumping capacities are 20, 30, 40 and 60 l/sec The sand if used should be up to 6m height Direct pumping to be used at higher heads up to 12m Installed pump capacity is based on mesqa design + increased by a pump performance margin of 25%.
Marwa improvement	No marwa improvement	Mesqa farmers will be free to select any combination of pumps which gives the appropriate installed capacity Marwa pipelines diameter 160, 180 and 200 mm The valves are butterfly valves with diameter 150mm Minimum operating head of one valve is 20 cm with discharge 20l/sec.
Institutional improvement	Establishing WUAs at mesqa level only	Establishing WUAs at mesqa level, Branch canal WUAs and District water council

Source: IIIMP, training manual.

2.6 On-farm improvements

Based on the experience of IIP-W10 pilot area (6000 feddan), which tested marwa-level and on-farm improvements (Gouda, 2009; Dutta, 2013), on-farm improvement projects funded by the World bank/AFD and IFAD are aiming at the following objectives:

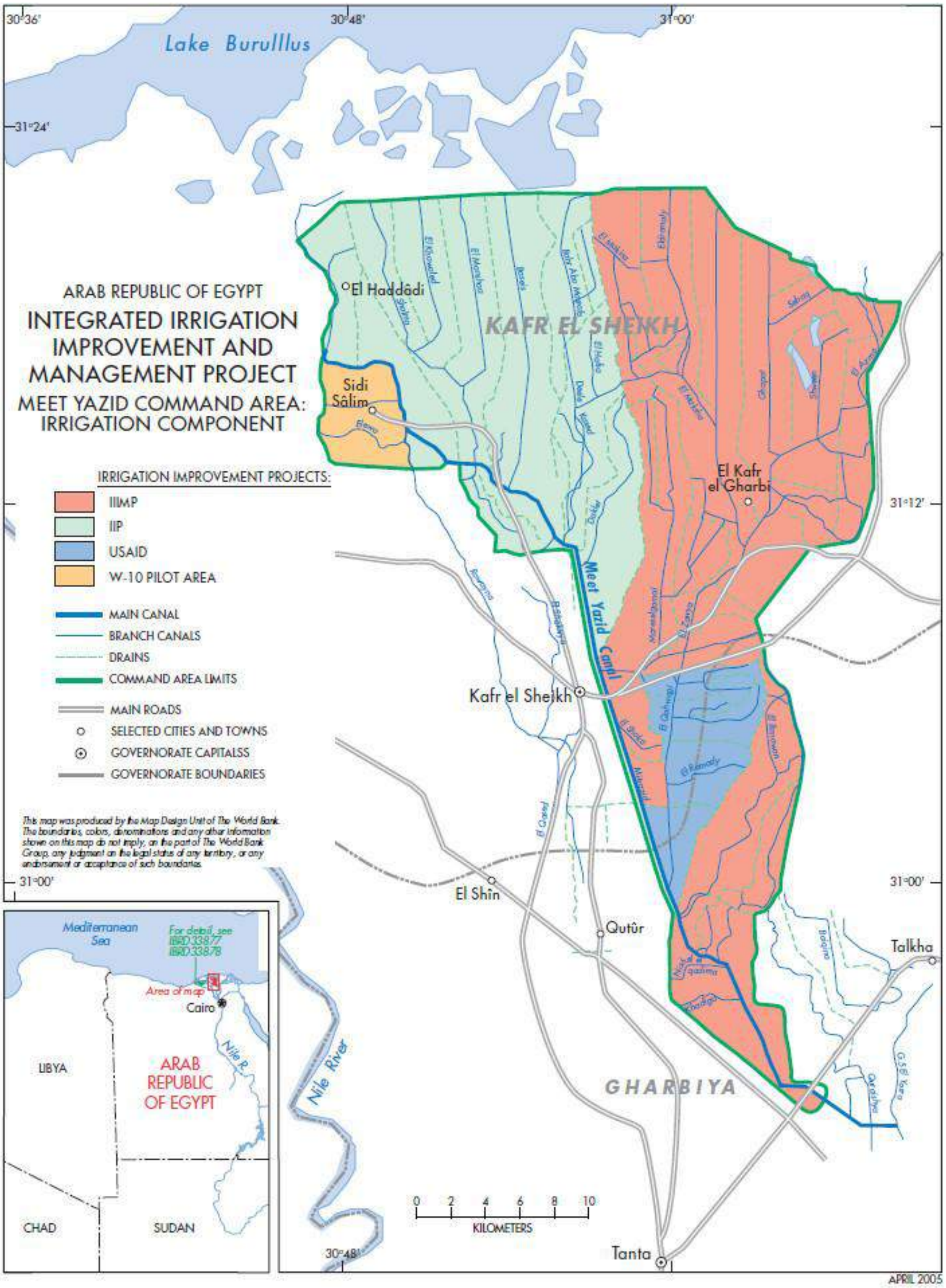
- Replacing *marwa* ditches with a pressurized pipe and valve system, based on the length of the *marwa* ditches and the consent of the farmers.
- Land leveling of the plots.
- Promoting water management techniques like irrigation scheduling, etc.
- Organizing farmers of a quaternary canals in Marwa Committees.

Marwa improvements are expected to have the following benefits (IFAD, 2009; World Bank, 2010; Gouda, 2009):

- Decreased costs: reduced irrigation time (less time to fill pipes) and maintenance costs
- Saving water resulting in increased yields due to increased farming areas
- Increased benefits: increase yields because increase of cultivated areas
- More equal and quicker irrigation
- Less work and waiting time, anyone can operate the marwa valves
- Less flooding from neighboring fields and clear boundaries reduce conflict among farmers
- Improved health: reduced risk of bilharzias

Such marwa-level improvements are currently being implemented as an additional option to IIIMP (OFIDO project), or as part of an upgrading of IIP1 pump stations (FIMP project).

Figure 5. Major development project in the MYC command area (Source: World Bank 2005).



3 Survey observations on IIP/IIIMP

The largest share of the irrigation infrastructure in Meet Yazid has been improved technologically in recent decades. In this section we look at the improvements made under the two phases of the Irrigation Improvement Project (IIP) and the Integrated Irrigation Improvement Management Project (IIIMP).

3.1 Macro-level infrastructure and continuous flow

The establishment of continuous flow (CF) in branch canals was an essential component of the IIP package. Most farmers confirm that it is the promise of continuous flow –having water continuously available for pumping in front of their intake– that convinced them to sign in for the project. Engineers have therefore used this promise quite liberally, even though it was becoming clearer and clearer as time went by that it would probably not be fulfilled. Many farmers, expectedly, expressed resentment at the fact that water supply had not been improved, and in frequent cases was even perceived as having become worse.

Continuous flow was expected to be assured by the installation of automatic radial gates which would maintain a minimum water level in the branch canal, ensure equity between head and tail ends, and avoid the over-irrigation caused by the uncertainty in supply. A remodeling of the canal was also made necessary to divide the canal in several reaches that would each be controlled by a radial gate.

No branch canal in the MYC area has so far been operated under CF. As a result, the 120 regulators in place have often been perceived, and effectively acted, as a hindrance to the flow of water, in particular because of the collection of garbage and the narrowing of the canal section. Consequently they have been tampered with, kept wide opened, by-passed or destroyed. In places like Abu Mostafa canal they have fuelled farmers' anger because they reduce the (already limited) flow and because their requests to have it removed (what farmers eventually did in nearby El-Hasafa canal) have not been answered (see IWMI-WMRI report 8).

The reasons for the non-application of continuous flow are several. Some are structural, since it seems that the proper remodeling of the canal has rarely been done, because of costs (that were to be supported by the Ministry) or difficulties in accessing the banks and implementing the work. The actual canal profiles are often deeper and wider than the original design profiles, which have been taken as initial design assumption for CF. The remodeling of canals to design values for the whole MYC area would be an immense operation, which at this stage is not any longer considered. Other reasons are managerial, with the alleged difficulty to implement continuous flow in one particular branch canal if it is not implemented at the same time in all other branch canals. Others may be bureaucratic, as some referred to the lack of incentives for engineers and most particularly gate operators to implement a system that has the potential to make their very function redundant (APP, 2007; Hvidt, 1998). Whatever the reasons, there seems to be limited support among managers to the idea that CF could be implemented, and little expectation from most quarters that it will.

If continuous flow is to be abandoned as a management idea, it will still remain very important to improve the predictability and adequacy of water supply at the branch canal level, to re-design the capacity of the pump in accordance with the duration of water availability (at the end of the canal, and not at its beginning) and to adapt PS intake levels to actual water levels.

Figure 6. Branch canal hardware to establish continuous flow

Mask modules to control discharge at the head (1)		Mask modules to control discharge at the head (2)	
Automatic gates, opening automatically based on downstream level		Automatic gates, opening automatically based on downstream level	
The gates are now left fully opened; but are a significant hindrance to the flow		The gates are now left fully opened; but are a significant hindrance to the flow	
Gates obstruct the flow and accumulate garbage (1)		Gates obstruct the flow and accumulate garbage (2)	
The gate has been fully removed		A bypass of the regulator increases discharge	

3.2 Actual use of the pumps and farmers' strategies

The IIP technological package, of which the Collective Pump station (PS) and the piped mesqas (and sometimes marwas) are the main components, while quite uniform at the design stage, has followed different 'trajectories', after being transferred to farmers (see Figure 35). Broadly speaking we can distinguish between those improvements which are in disuse and those which are working for the planned purpose of water management, with further categories showing why and how the technological package was adopted/refused, adapted, appropriated or abandoned. This also teaches us broader lessons about the appropriateness of the technology under different conditions.

3.2.1 Technological packages in disuse

There are several different reasons why some PS are in disuse. In the first place, farmers may have refused to officially receive the station because of an internal conflict, or because specific request made to the administration (e.g. pump capacity, number of valves) had not been considered. In other cases, the engines and sometimes the pumps have been stolen and farmers have not been able to collectively decide to replace them. Other causes for abandoning the station altogether include breakdowns or conflicts.

3.2.1.1 Refusal to receive the pump station

In several cases farmers refused the IIP/IIIMP package and preferred to continue as they were, because they did not see the benefits of the 'improvements'[2], feared the costs, or were apprehensive to depend on the others for their water supply. People continued to use the individual lifting devices they were using before. For example, along the Halafy canal some farmers were afraid of the money they will have to pay, and also not sure about who would control the pump. Another (rare but drastic) way of refusing the IIIMP package, especially when it has been imposed with minimal farmer consultation, is for farmers to take advantage of the interruption of the project (due to delays in implementing the electricity network) to sabotage the stations that have not yet received their pump sets and have not yet been officially transferred to them.

On the Nesheel Branch Canal, at the head end of MYC, several PS have no door because they appear to have been broken away. There are no pumps. A group of farmers on this canal talks about the objections they have against *tatweer* (improvement = IIP project). They fear the cost of irrigation. Others fear that the pipelines will get blocked, but that they will not be able to see (and repair it). They are also not convinced that it is possible to irrigate different crops with one valve, or that it will deliver sufficient water, or that the PS can irrigate the very long plots of land that they have. When asked about the sources of their ideas the farmers state that they have heard from other farmers at another canal, where they have even destroyed the pipelines of the marwas, because they did not want them. These farmers do not seem to be informed on the basis of direct experiences and observations of working PS, also because there are none in the immediate vicinity. But it is clear that the word of mouth is not good at this head-end canal.

[2] The use of the policy label of *tatweer or* 'improvement' for the technological interventions of the project, prescribes a normative idea, namely that those interventions are indeed an improvement (Wood, 1985). This makes it difficult to see that farmers may have legitimate reasons to refuse 'improvements', when these interventions do not improve their particular situation. Without this recognition, the refusal of the benefits of a national project, becomes unintelligible and easily classified as irrational responses of uneducated farmers. Hence, the reader should take care with interpreting the label of 'improvement' for the rest of the text.

This contrasts with other more downstream areas, for example on the Bashair branch canal, where farmers were awaiting completion of the works. They also did not have direct experiences, but have heard from other farmers in the area, or observed PS installed in the Mares el Gamal Canal, that it worked well, so they wanted to try it.

At the intake of El Halafy a farmer confirms that they have an IIIMP PS, but they did not yet deliver the equipment. The older man with 4 feddan does not want it because he is at the head of the canal. Now he can irrigate when he wants to, but that will not be possible with the collective pump. He explains by saying about the collective arrangement: "If I drink by myself it is all right, but if others want to drink as well, it will be difficult". This illustrates the fact that the IIP concept imposes a collective equipment on a group of farmers for the sake of greater equity, but that this comes at the expense of those located close to the canal, who will be losing the flexibility they enjoyed by being along the canal. This promise of a greater equity is indeed realized when enough water/pumping capacity is available for the pumps to serve all farmers, as in parts of Daqalt canal area, where farmers confirm the benefit of a more equitable distribution.

A few stations visited had not been formally 'received', that is, the ownership of the station had not been transferred to the Water User Association, since no one had signed to receive it and the equipment had been left idle since its completion. The reasons for not receiving the pump stations included:

a) disagreement on the level of the pipe intake (farmers arguing that it is not low enough and that they therefore cannot abstract water from the branch canal when the water level is low, as they can do with their IPs);
b) disagreement on the definition of the command area of the pump station, farmer finding that the station is pooling together people who don't want to work together
c) feeling that the area is too large and should be served by two pump stations, which is refused by the IIIMP;
d) disagreement on the pump capacity provided (farmers arguing that the capacity is too small and demanding a more powerful motor);
e) the works have never been completed (while the contractor says the project is over and he is no longer responsible);
f) severe internal conflict between farmers;
g) overt hostility from a group of farmers towards the project itself, since they did not ask for it.

An example of (e) can be found along the Gad Alla canal. A majority of the pump stations along that canal is not working and several of them have not been received by the farmers because they have construction failures, although the contractor claims to have completed his work. In one case at the tail the farmers claim that they have never signed for reception because the work (the mesqa pipe and the valves) were not finished and the PS as a whole never worked to their satisfaction. The contractor implemented the design for the pump-network of the IIP engineer which included 11 valves for a PS of around 32 feddan. The farmers complained about the unequal distribution of the valves: 7 for 12 feddan and 4 for 20 feddan. However, the engineer did not want to change this and did not ask them for their opinion. The contractor never finished the work, but claimed to have finished it, and IIP did not act on the situation after several visits to the regional offices. The farmers refused to pay for the works, but were summoned to court by IIP. They are convinced that they will win the dispute, since they did not sign for reception.

On the Moheet, a station has never been received and is not complete, since the pumps have not been delivered and installed. This is a group of 13 farmers, with two of them (affluent farmers) having a conflict regarding the position of a valve; the main pipeline goes along the road and is expected to serve four marwa pipes; one or two of these marwas have not been put in place because of this conflict; whether the issue is having the valve in front of one's house, or whether this has something to do with controlling the water to the marwa that goes along the house was hard to ascertain, but the conflict has impeded the completion of the work. Half of the investment has been made in vain.

In Mares el Gamal canal, one station has been left incomplete because of the conflicts between farmers. One individual had not been willing to join the project because the area earmarked for the construction of the pump-house would have encroached on his land. After his neighbor agreed to have the station fully shifted to his land and after the network and the station were constructed, he claimed his right to be part of the group. To this day, the group has asked him to pay compensation to his neighbor but he has so far refused to do so. As a result of this conflict, the contractors have stopped the implementation and not delivered the pumps and the motors. In a recent visit in spring 2015, we were told that the farmers have finally got together and requested IIIMP to finish the PS.

3.2.1.2 Theft of pumps and of other collective equipment

One of the major problems that has severely affected water users in using the IIP and IIIMP technological packages is theft. Theft is a major problem for the functioning PS in the region and may have increased since the 2011 Revolution. In some stations, pumps (i.e pumps and their engines, or the engines alone) have been stolen two or even three times. In some canals 5 to 10 pumps have been stolen in one night. This concerns the stealing of diesel or electrical engines, but also suction pipes, valves and –sometimes– transformers, or even wiring, which deliver the electrical current to the pump stations (one farmer mentioned that even the batteries of the receivers of the mobile phone companies were stolen). Such theft effectively takes the collective pump station out of operation and creates a serious problem for farmers who need to irrigate. In our core sample of 49 PS (which does not consider stations that have been abandoned because of thefts or another reason), we found that 30 of them had never experienced thefts, nine had seen their engines stolen once, and three stolen two or three times.

Our global survey of 640 PS found out that 26% of the pump stations had had their motors stolen at least once, of which 22% had their pumps stolen twice and 3% thrice. Figure 7 shows the distribution of both stolen pumps and abandoned PS. 18% of the PS were found to be out order. In most cases (16% of the total) pump houses were empty, and in a few cases the motors could be seen but were not in working order. From the figure it can be seen that the abandonment of the PS is sometimes a consequence of the motors being stolen, but not always. Of the 101 PS found empty, 35 did not report theft of motors which means that the one third of the abandoned PS are in disuse because of other reasons such as mechanical breakdown or severe conflict.

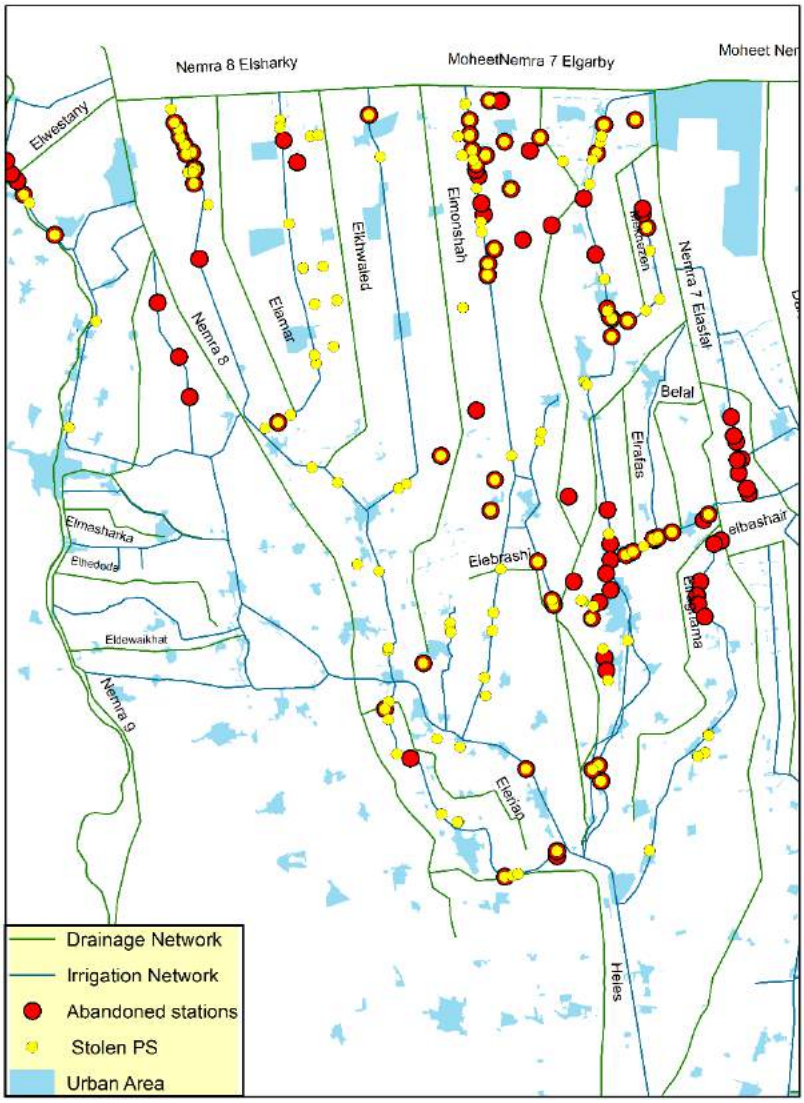
Another case of theft, less frequent and less damageable, is the stealing of the valves, also observed in several instances. Farmers complain that it is difficult to find spare parts but sometimes succeed in having local workshops manufacturing the valves. In Bahr Nemra electricity has been connected but the electric wires were stolen.

The conditions under which such thefts take place are various, but there are some commonalities. First, it is abundantly clear that thefts are chiefly occurring in distant areas away from villages, where there is no control from the users or their neighbors. The terminal parts of Shalma and Daqalt canals are good examples of such conditions. Another factor is the existence of roads. The final reach of

Daqalt offers a very clear illustration of this, where the last two stations accessible by car have been stripped of their equipment, whereas three stations located on the left bank and with no access roads, still have their pumps in place.

Figure 7 shows the spatial distribution of stolen pumps (once, twice or three times) as well as the villages and confirms that most thefts occurred in areas distant from any village or dwelling.

Figure 7. Spatial distribution of stolen pumps (yellow) and abandoned PS (red)

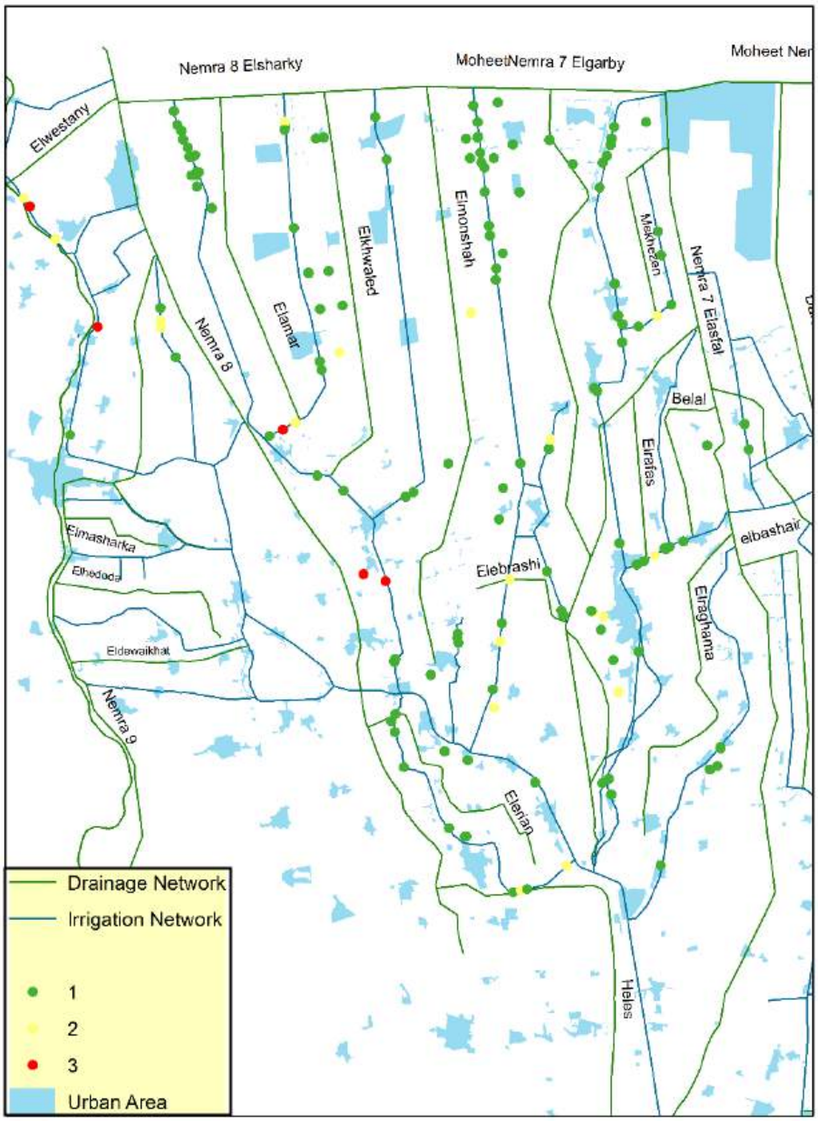


Close to villages, in contrast, people indicated that theft was less of a problem because of the constant social control. The snatching of pumps is especially done at night when there are no people in the field to keep an eye. Since the revolution of January 2011 along with a general decline in security, the problem of theft has increased, also because it is not safe anymore to be in the field at night.

In one instance, 8 diesel engines were stolen along the El Mesk branch canal in one time. The thieves worked with a crowbar to open the pumping house and steal the pump engines. This happened after

11 at night when people go home. The thieves know when to attack because they know when people leave. Nonetheless, the water users had a suspicion about the thieves, so they went to the police and passed the number of a motorcycle plate. But the police indicated that they could not do anything about it. In Bosees canal, though, two thieves were caught and the police successfully pressured them into bringing back the stolen pumps. In another location, farmers did buy another engine after it got stolen, to be told by the police that this model was coming from another pump station which had also been stripped of its pumps.

Figure 8. Spatial distribution of PS stolen 2 or 3 times, with villages



On several occasions, the impression of farmers is that organized groups with prior knowledge are stealing the pumps and know what they are doing. For example, along the Moheet canal, 7 electrical pumps belonging to 5 stations were stolen in one night and also some transformers. The transformers were replaced by the Ministry of Electricity, but the pumps remain the users' own problem. A trip along Mares el Gamal also showed that a transformer and 7 pumps had been stolen. The reason why farmers think that the thieves have prior knowledge is that one needs to be able to swiftly connect and disconnect the electrical wiring from the pump. This is a specialist job requiring the right equipment in their view. In some case the timing of this theft, not long after installation, also suggests this. There is a widespread belief among farmers that the technicians who install the pumps and connect the electricity for the contractors are involved, however it is difficult to prove this. One farmer also blamed the theft on drug addicts. In many cases it is clear that thieves know what they are looking for and are said to be 'specialists' (for example the more expensive air-cooled pumps are most 'popular' with thieves).

Farmers have taken a diversity of (creative) measures to protect themselves against theft (Figure 10):

- A padlock, obstructing the door, or raising the fenced wall of the IIP pump house are the most frequently observed measures.
- Contracting a guard with gun for several pump stations (sometimes building a quarter on top of a pumping house so that he can oversee the area and stay overnight).
- Putting a watchdog in the pumping house at night.
- Putting the door under electrical current.
- Closing the door with concrete, leaving just a small hole that makes it difficult to steal the pump without breaking the whole construction (on the Monshah branch).
- Building a concrete wall after the door, leaving only a narrow space for somebody to slip through, making the removal of the pumps quite difficult.
- Construct new separate or attached pump houses to protect their collective and private pumps.
- Removing the diesel engines (or one out of two) during the winter season and keeping them at home to avoid their being stolen
- Welding the pump to its support to prevent its removal (El Moheet canal).
- Filling in pump-house openings: The weakest points of the stations are their small openings that allow the light to enter and the air to circulate. The intervals between these openings are easy to break, which creates a bigger hole which can in turn be enlarged, as to allow someone into the station. As a result these openings have frequently been filled in with concrete, or reinforced with iron.
- Theft-proofing the pump-house with concrete and iron

Figure 9. Pump station with a reinforced concrete protection

Figure 10. The theft of IIP/IIIMP infrastructure and solutions

A diesel pump stolen after delivery leading to abandonment		A stolen transformer causing electricity cut	
The door of the station is narrowed so that engines cannot be taken out		New IIIMP station, enlarged to accommo-date a diesel pump (Halafi canal)	
Iron grids added to the station openings		A separate shed for the extra diesel pump	
A closed pump station with minimal opening to prevent theft		An extra quarter for a guard to protect the pump	
Reinforced IIP station in Bosees		A pump station protected by a mesh	
Pump house openings almost sealed		A newly constructed building for electrical pump	

The most spectacular innovation to discourage theft was also encountered in the Moheet canal, where farmers have shrouded their pump station with a thick layer of reinforced concrete, and installed two successive sturdy iron doors provided with several locks (Figure 9). This solution, which has now been replicated by another nearby station, has been made necessary because "the area is isolated from the village and no one can sacrifice himself to stay at the field at night". It has come as a total cost of 10,000 EGP.

The theft of a pump is often a critical moment in the functioning of a water users organization and the trajectory of a pump station. Farmers have responded differently to such a collective challenge as a result of which the pump stations have followed different trajectories (see Figure 35). The indicated options sometimes overlap:

1. Replacement of the stolen motor/pump (possibly buying a new type; see section 3.2.3)
2. Fragmentation of the collective (some farmers agree to buy new motors, or only one, others opting out; see section 3.2.4)
3. Abandonment of the station (see next section 3.2.1.3).

Farmers are not always informed about the fact that they need to pay for the replacement of a stolen pump. Some farmers are asking not to pay for *tatweer*, in case the pumps were stolen even before use. Indeed, because of the delay observed in the completion of the work in IIIMP stations (notably due to the electric connection), during which installed pumps could be stolen, the contractors have been made responsible for the equipment until formal reception by the users. They have a contractual obligation to replace every pump that is stolen before the official date of *reception* of the works by the farmers. This is why all the IIIMP stations waiting for an electric connection have not been provided with pumps.

3.2.1.3 Abandonment after use

The abandonment of a PS can be caused by the stealing of pumps, technical difficulties or breakdown, associated with either a lack of consensus for replacing or repairing them, or a lack of interest to do so.

Farmers are disheartened by the theft or the breakdown and the decision to abandon the station follows from the association of a negative experience (e.g. the operation of the station was causing social conflicts) with the existence of (not too costly) alternatives. In most cases this happens for 'parallel (piped) mesqa'. In W10 and in other small branch canals, it is very common that the abandonment of the station merely results in farmers using their individual pumps again (which in most cases were not removed) at the head of the marwas, as a substitute for the nearby and idle valve (see Figure 12). It is easy to understand that in such conditions the CPS brings limited benefit to farmers, who can all abstract water directly from the branch canal. In other words, this is a situation where collective pumps should not be installed unless requested by farmers.

A stunning illustration of this situation was found in the Ariamon canal, in a pump station irrigating 55 feddan and shared by seven farmers. The two original pumps sets can be seen in the pump station but have *never* been used during the 10 year period since the construction of the station (Figure 11). Except for the recent theft of some minor parts, they are in their original state and presumably in working conditions. Farmers found themselves in conflict with the engineer who initially said that irrigating one hour per feddan would be enough. They also complained of the too high intake which also has a slope in the wrong direction. Further, conflicts arose between farmers as to what should be done. For example, they could never decide whether the pump stations should be abandoned, in which case the pumps and motors could be sold instead of being left rusting. The situation resulted in a stalemate, farmers reverting to their individual pumps and the four pump sumps corresponding to the earlier marwas that were still in place. A few meters away, the whole equipment has been stolen, the pump house is fully open and merely serves as a shelter for the IPs that abstract water directly from the pit of the station (Figure 11).

Figure 11. Unused pumps (left), individual pumps using the pit (right) (Ariamon)

Another situation where farmers have an alternative is where the mesqa has not been filled in, or can be reopened.

Yet another example coming from the Ariamon branch canal illustrates how abandonment can happen very early on. In this 10-year-old IIP station serving 45 feddan and received by the farmers, two severe problems occurred after implementation: first they realized that the pipe intake of the station was very high; second, the main distribution line was broken after a couple days of use. Since that day, farmers have kept the two motors at home and have never used them (Figure 11), refusing to pay for the project. According to them they were also asked to pay for the lining of a long marwa which was requested but never executed. As a result of this conflict and of their refusal to pay, some farmers have been jailed several times until the case was deferred to the court which decided that the 23 persons concerned either had to pay or would go to prison. This kind of conflict seems to be related to the lack of guarantee given to farmers in the case IIP contractors are unwilling to admit responsibility and to repair the damages.

Figure 12. Valves and distribution pipes along the branch canals

In Bahr el Nour area, replacing the stolen pumps was said to be hindered by the fact that only 20% of land owners cultivated their land, the rest living outside and just receiving the rents, with limited incentive to invest.

3.2.1.4 Replacement of the pump station by a concrete pipe

In other situations the decision to abandon the pump station is associated with a much more radical alternative: replacing it. The pump house and the main pipe are removed and the materials are sold to be invested in a new system. The 35 cm PVC mesqa pipe is replaced by a 80-100 cm diameter deep concrete pipe that connects with the canal and in some cases the drain, which allows flow in both directions. The deep pipe (3-6 meters) has short branches that serve rectangular or round outlets from which the water is abstracted. Farmers pump from these pits, as they used to do before IIP from the earthen mesqa. The main pipe has a vertical airshaft roughly every 50 meters for airing and cleaning of the pipe.

Figure 13. Deep piped-systems from intake point near canal, individual pits, to outlet gate at drain

This improvement initiated by farmers has been observed mostly in the Sidi Ghazi and El Riyad irrigation districts. For example, one group was given a pumping station with a high-level intake which could not abstract water in times of low water levels in the canal. They excavated a ditch and fitted in a large concrete pipe, with its basis at the level of the canal bottom, which can convey water swiftly along the (former) mesqa. In another IIP area, farmers have done away with several stations and pipes and replaced them, at their cost, by such buried pipes. In the Daramally and El-Marbat canals, farmers are installing similar mesqa pipes, in some cases as a preemptive move to avoid getting a new PS if and where the IIIMP project is extended to the area. In other cases, by installing such a deep pipe farmers collectively improve the water access of their mesqa. The Daramally canal has older covered mesqas, with pipes installed 10 years ago because of the unstable soils. In the downstream reach of Shalma canal, replacing the mesqa by a large pipe was motivated by the will to avoid the sequences in which the mesqa functions as a drain (during off periods), gathering salty water that needs to be dispensed with through pumping. Along Ghabat and Halafi canals, some mesqas have been replaced by one-meter-diameter pipes. These piped mesqas service not only agricultural lands, but sometimes also fish ponds in these areas, which more generally use a lot of pipes to interconnect ponds and waterways. Along Abu Mustafa and its sub-laterals several of these deep pipes have been installed in the middle stretch of the canal where IIP stations were most seriously constrained by high intakes and low water levels in the summer and very short irrigation turns. Several of the newer ones allow water inflow from both the canal and the drain when the water level in the canal is low but high in the drain. All these examples of local improvement point to a cheap improvement technique that improves equity at the mesqa level, while being well accepted by farmers.

Local builders, craftsmen and farmers developed this indigenous form of improvement since the new millennium. During the 1990s, Egyptian builders gained experience with pipe use, network installment and leveling by working for construction companies in Arab countries such as Jordan and Saudi Arabia. After coming back, they applied this practical knowledge in the fertile, flexible and irrigated soils of the delta. It started with importing a rudimentary and creative technology to cheaply manufacture concrete pipes from Mansoura, according to local builders. The motor of a tractor with gear box powers a driveshaft that is connected to round metal moulds that contain a steel wiring and in which fluid concrete is poured. Through the gearbox a worker spins this circular construct at different speeds so that centrifugal forces spread the concrete evenly over the sides and excess water is released until the concrete hardens and the pipe is ready to dry. Local workshops have increasingly adopted this pipe-producing technology all over the delta.

Figure 14. Local production of big pipes for mesqas

Originally these types of pipes were used by farmers in and around their house and courtyard, but soon the potential use of such cheap and locally produced pipes in agriculture and later aquaculture became clear. In a water-abundant delta, the applications of such pipes are endless and so the demand grew steadily. This local form of pipe production grew into a small contracting business which provides jobs to people. From 5 to 10 contractors work on all kinds of applications in the Sidi Ghazi and El Riyad districts. Every contractor has developed a different style of doing the work and some have come up with innovations to the system, such as pre-cast concrete boxes or a gate on the drain which is both inlet and outlet. In most cases the application of such pipes in agriculture are to improve traditional earthen mesqas, only in some cases these piped-systems were used to avoid IIP improvement or to actually replace already existing IIP improved systems.

This artisanal system creatively combines elements of different forms of irrigation improvement. The piping of the mesqa is an element that is clearly derived from IIP/IIIMP with the potential benefit of water savings. The vertical airshafts on the main pipe seem to be inspired by the man-holes of sub-surface drainage networks. The outlets are not unlike the outlets on the earthen mesqas, although the latter were shared by more farmers. Yet, the local piped system is also a partial response to the IIP/IIIMP design, by promising a number of advantages, such as:

- a simple, cheap and locally produced system, designed in situ incorporating farmer requirements (more outlets)
- a deep and sizeable pipe with continuous access and more storage capacity adapted to the rotational system
- a flexible system in which farmers are free to irrigate when it suits them
- the option to get water from canal and drain
- lower maintenance requirements

First and foremost, farmers invest in this new system because it frees them from the collective action of a shared pumping station, allowing them to irrigate whenever they want

Disadvantages of the system are:

- the use of saline drainage water
- seepage of saline groundwater into the pipe,
- higher individual pumping costs,
- doubled investment costs in case IIP improvements are replaced (IIP still needs to be paid)
- downstream impacts of higher water diversions

3.2.2 Working as planned

In relatively few occasions the PS are entirely working in the manner that was planned. Pumps and networks that function as planned are often serving limited areas and have a good water supply (and pump capacity); or have been implemented only recently.

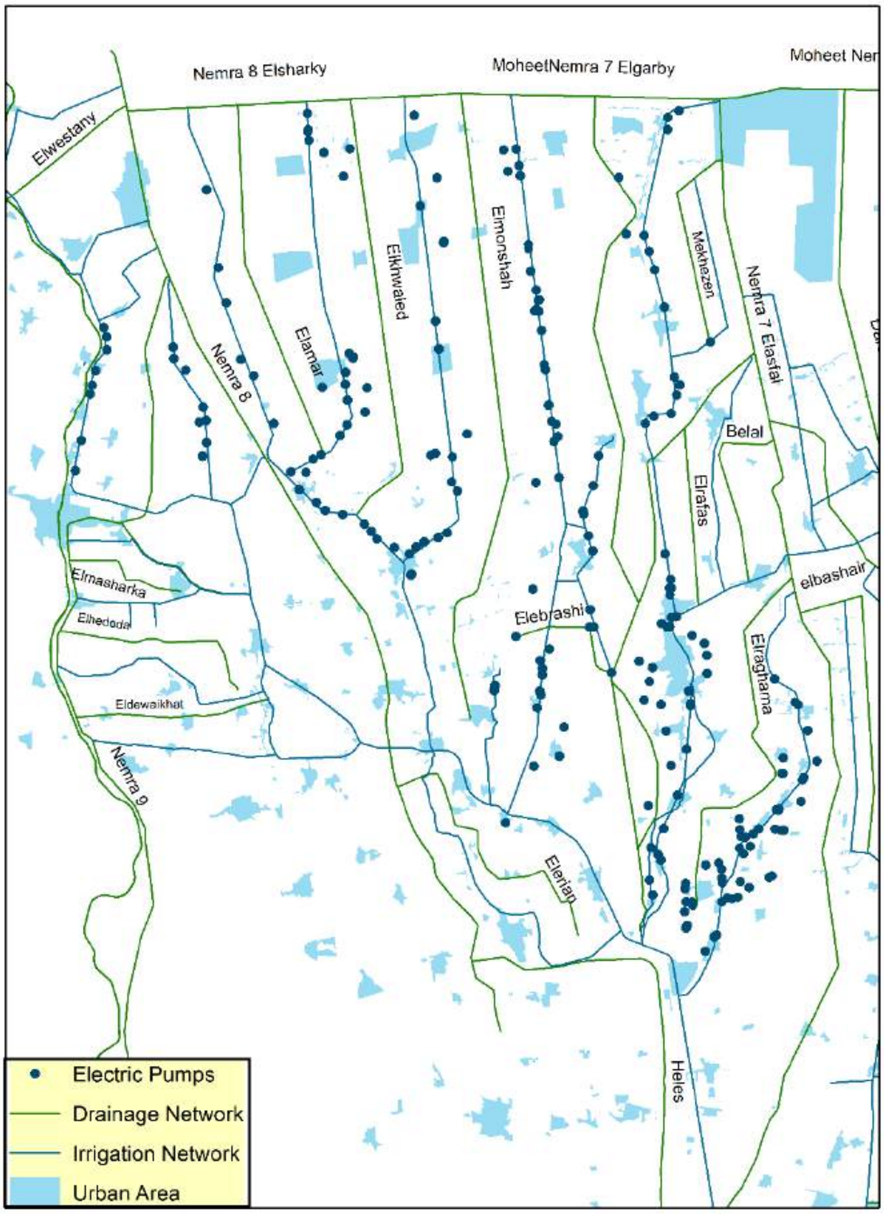
The following sections document the numerous types of adaptations implemented by the farmers; while section 5 provides an overall analysis of the reasons for such adaptations.

3.2.3 Changing or adding motors/pumps

In many of the IIP pump stations at least one of the diesel motors has been replaced or added by the users (we have not investigated the changes in the pump bodies themselves). Different reasons include theft (needs to replace the motors), the will to increase the pumping capacity, malfunction or declining pump power.

When users experience that the capacity of their PS is not sufficient to irrigate their service area in the limited time during which they have water within the rotation, they have a strong incentive to replace one of the pumps by one with a larger capacity. Another possibility is to add another pump to the station, either inside the pumping house or outside, but abstracting water from the same pit and injecting it either into the tower (IIP) or the main pipeline (IIIMP), the former case being more common than the latter. Out of 640 stations, 302 had replaced at least one motor (whether diesel or electric). Around 41% of those stations reported cases of thefts, meaning that at least 59% replace one or more engine for reasons other than theft.

Figure 15. PS with at least one electric pump



Out of a total of 1288 initial diesel pumps (pertaining to 640 PS that had 1, 2 or 3 pumps), we found 890 diesel pumps (of which 812 were working) and 288 electric pumps. Electrification has therefore expanded to approximately one fourth of the stations, with large differences between canals, as can be seen from Figure 15. While some canals (e.g. Daqalt or Bosees) had many electrified pump stations, others such as Ariamon had none.

The potential benefits of an electrical pump in place of the diesel one are:

- electricity is substantially cheaper (on average 67% of diesel running costs, see later)
- eliminating the burden of buying/bringing diesel to the station
- obviating the risk of diesel shortages and/or hikes in prices, as was observed in spring 2013 when the country faced a nationwide supply crisis

- reducing noise pollution
- taking advantage to buy a motor with higher power to increase the abstraction capacity

On the other hand, shifting to electricity comes with a couple of drawbacks:

- If the farmers (illegally) connect their station to a nearby domestic electric line, they will impact voltage in the area; and in practice be often unable to use the pump in the evening, when consumption is high.
- If they choose to arrange an electrical connection with the Ministry of Energy, this will significantly increase the cost of the option. In general, farmers either pay the electricity company a fee for connecting high power equipment to the grid, which is proportional to the horsepower of the pump, with 400-700 EGP/HP. Another option is to pool several stations together and pay for the installation of a transformer.
- Their pump will now be exposed to electricity cuts. These cuts have been extremely frequent during the year 2013 and are a fact of life in the countryside, generally speaking, in particular since the Revolution of 2011. These cuts can sometimes occur every day, and typically last a couple of hours.
- Adopting a higher power motor may create problems of over pressure in the network and damage to pipes/connections.

Of course electricity cuts interrupt the irrigation, the rotation on a mesqa and it is particularly frustrating for farmers when this happens during an 'on' period on their Branch Canal. By the time the electricity is back, the water may be gone and they are forced to wait until the next 'on' period.[3] even if the cut is more limited in duration it disrupts the possible rotational arrangement that was being followed by farmers; with the question of whether the farmer impacted has to skip his turn or whether the full schedule is to be shifted. Since farmers cannot run such risks, especially not during the critical period of transplanting rice, they need alternative means of irrigation. Using electrical and diesel pumps, in parallel, or conjunctively, is a good risk-management strategy. Having both collective and individual pumps adds to this intricate picture.

With stolen, weak or malfunctioning motors the question is whether farmers can collectively agree on the necessity to buy a new motor, and whether they have the capacity to come up with the money needed. To reduce the cost, farmers can also buy a secondhand motor. A market for such equipment has developed -for example there are well-known shops in the city of Mansura– partly supplied by stolen devices.

The cost of electric motors varies a lot according to the capacity and the quality of the equipment. Prices commonly vary between 2000 and 8.000 EGP. But the total cost of electrification, when special wiring and transformers are needed, would be around 15 to 20.000 EGP for one PS (see more detail in section 5.5).

[3] Interestingly power cuts are welcome by farmers at the end of branch or sub-branch canals, because water has then time to flow downstream without being fully used on the way.

Figure 16. Changing or adding pumps/engines

IIP station with one pump added to the two original ones by farmers (1)		IIP station with one pump added to the two original ones by farmers (2)	
Three IIP diesel motors replaced by electric motors		Original motors replaced by more powerful ones	
Only one motor changed to powerful electric engine		Mixed stations, with both electric and diesel pumps	

3.2.4 Fragmentation

After the introduction of a PS and a piped mesqa, the corresponding collective of farmers can split, or become fragmented. In the design process different groups of farmers were sometimes grouped together under one pump station by the engineer, without taking into consideration local social realities and physical experiences of sharing a water source. These farmers may have no experience of working together, or worse, be in conflict for whatever reasons (different classes, families, villages, etc.). Conflicts can also arise among farmers who were used to abstract water individually from the mesqa but now find it difficult to share a collective network. These conflicts are typically heightened when water is not sufficient, either because the BC is not well supplied, and/or because the pumping capacity is insufficient, and/or because the network is large and complex. Farmers with alternative means of irrigation then may promptly evade conflict with the rest of the group by fragmenting and leaving the collective. Understandingly, most farmers opting out are farmers who have lands near the canal or the drain and can therefore abstract water independently. For them, the additional transaction costs of getting water through a collective pump and collective arrangements are too high, as compared with their previous direct access to water from the Branch Canal; and/or that their share of water during the 'on' period is less than what they can abstract individually.

An indication of fragmentation is given by the fact that the number of working pumps in our survey (640 PS) was found to be 85% of the initial number of pumps, showing a decrease in the overall capacity of the PS (although this is partly compensated by the fact that in some cases new motors have a higher capacity than the original ones).

Nevertheless, the farmers stepping out still have to continue paying for the PS. This means that a part of the land is subtracted from the service area of the PS and this increases the supply-demand ratio, that is, the availability of water compared with farmers' needs. The supply normally remains the same as there is no re-design of the pump capacity based on such a change. This explains why remaining farmers in the group have no problems with individuals willing to drop out. For example, a pump station in Masharqa canal (W10) was designed with 2 pumps for 60 feddan. However, 30 feddan were excluded because the farmers were not happy with each other. The remaining 3 families that are now operating the PS are very satisfied with their pumping capacity because it more than meets their demands.

Another typical case of conflict could be observed along the Moheet canal. A pump station was to serve 37 feddan but actually only served 31, which belonged to one family only. This family has a problem with the plot of six feddan that belongs to some stranger they have been in conflict with for many years; they are ready to pay for the cost of these six feddan but are adamant that they will never share the same pump with their neighbor.

An interesting twin example of fragmentation is provided by the Ariamon branch canal: one station is used by the workers of two brothers belonging to a former large landowning family to irrigate 38 feddan. Two additional valves are serving five and seven feddan respectively. These two farmers were pooled together with the large farm against their will and very reluctantly dealt with the (numerous) workers of the landlord. Arguing issues of low pressure in the pipe and frustration with the shared management of the pump, they have opted out and reverted to their earlier individual pumps, which provide a much better discharge. However, they are incensed by the fact that they still have to pay for the improvement. At the next pump station, the opposite situation can be found: 10 feddan belong to a landlord while the remaining 30 feddan belong to small farmers. When these saw that their names were under the same station, they asked to be separated and an arrangement was found with the landlord who preferred to revert to his much bigger and already existing pumping devices, after it was agreed that the others would pay for his part.

In El Hasafa canal, a station was originally serving an area of 65 feddan, but after the two pumps were stolen farmers did not agree to replace them. Only the farmers cultivating an area of 20 feddan without alternative water supply did collect the money to replace one of the two motors. In a nearby station which was designed to serve 75 feddan, one of the two distribution pipes, which was serving 22 feddan, was abandoned and replaced by a small elevated canal supplied by two IPs abstracting water directly from the canal. The PS now supplies only 53 feddan. Likewise, in other places, fragmentation most commonly happens due to farmers with plots located close to the canal reverting to using their IPs.

In yet another case at the head of Mares el Gamal, the contractor explained that the fragmentation in this PS originated from the fact that farmers were divided, some opted out, and the rest did not select an operator to receive training from the contractor on how to use the IIIMP PS. The farmers were operating the PS amongst themselves. The impact of this could be observed when one of the farmers started up one pump but opened only one valve (the one for his field) instead of the required two valves. This created overpressure in the pipes and resulted in a leakage at the pumping house.

Another example comes from the El Khawaleed BC, where two brothers were originally incorporated in an 80 feddan PS, but could not use it because their land was too high and far for the PS; with little pressure at the level of their valves. Hence, they split from the main group and received permission to start using their IPs again on the nearby canal, until their problem would be solved.

3.2.5 Parallel use of PS & IPs

The original IIP concept was that installing PS at mesqas would dispense with the use of individual pumps (IPs). In fact these would be prohibited and the existing pump sumps removed. The PS would become the exclusive means of accessing canal water. However, the use of IPs is still ubiquitous in the *tatweer* areas of Meet Yazid. Many farmers use their IPs to access water from the canal or a drain (re-use) when the canal water delivered via the PS is not timely and/or adequate.

Both the parallel use of PS and IPs to access the same irrigation canal water and conjunctive use (the additional use of IPs to access different sources: drainage water or wells), are widely found in the Meet Yazid region. The parallel or conjunctive uses of PS and IPs greatly reduce the risk of being dependent only on the PS and improve the farmers' flexibility in accessing water. However, it is limited to the farmers that have access to either the canal or the drain, either directly or through some marwa or pipe.

The use of IPs limits the restrictive influence that the collective infrastructure is supposed to have on over-extraction and thus may cancel potential fresh water savings or increase the amount of drainage water re-use. But restricting use is associated with the principle of continuous flow. Under present circumstances, in the absence of continuous flow, the design capacity of the pumps is in most cases inappropriate to access water during rotations, and the use of additional pumps is *the only and unavoidable* way to meet requirements.

Supplementary use of IPs can be implemented in three different ways: 1) by setting them directly along the canals or the drains and supplying adjacent plots; 2) by using the former 'pump sumps' (collective lifting points) along the canals, when they have not been destroyed or when they are reconstructed; 3) by using the pit from where the pump station abstraact water. There are countless situations where PS and 'pump sumps' coexist side by side. These three situations are illustrated in Figure 17.

For IIIMP, parallel use is officially considered as a temporary situation when the works have not been completed. At the end of the project the diesel pumps set up in the station pit as well as existing pump sumps are to be removed and filled, so that the use of the pit by IPs will no longer be possible. The question is how effective the closing of pits will be to force farmers to irrigate collectively, whether this is possible (see above) or desirable, and what farmers would do in response. Indeed, it is apparent that there is a negotiation between farmers and IIP/IIIMP engineers about the removal of the former pump sumps and that in many instances the earlier system is eventually left in place, probably because farmers now put this as a condition of their acceptation of the project.

In the particular case of the recent IIIMP stations, whose completion was delayed because of the lack of electric connection, the existing pump sumps have of course been left in place and it is doubtful that in such a situation the engineers will have the bargaining power to impose their removal, when completing the project after several months or years of delay.

Pumping additional water from drains remains ubiquitous in IIP areas of Meet Yazid. A survey of individual pumping from drains undertaken by this project has shown, however, that reuse of drainage water was chiefly prevalent in the downstream part. Upstream areas (before el Wasat regulator) are much better served and only moderately rely on drains. All types of drainage water sources are tapped, not only main and secondary drains, but also tertiary drains along plots and, more surprisingly, even subsurface collectors: farmers use manholes to access water (although it may not be possible to pump for long durations); this practice seems to be limited to areas mostly growing rice, which generate substantial subsurface drainage.

Figure 17. Supplementary use of IPs

Individual pumping from the canal, remaining next to the PS

Individual pumping from the collective 'pump sump' that has been kept nearby

Individual pumping from the station's pit

In some cases farmers have also dug wells, but although this solution is increasingly observed from the apex of the Delta down to the latitude of Kafr el Sheikh, the upstream part of the Meet Yazid command area is quite well served and farmers did not have to resort to such additional investments (with some exceptions). In the downstream part, on the other hand, that is north of Kafr el Sheikh, groundwater is too saline to be used for agriculture. The pumps used to abstract water from wells can either be those already used for mesqa or drains, or be powered by a tractor for a bigger discharge (Figure 19). Most of these wells have been excavated in the past 15 years and the investment as well as the benefits drawn from their use are frequently collectively shared.[4]

[4] See IMWI-WMRI Report No. 7 'Survey of groundwater use in the central part of the Nile Delta' for more details.

Figure 18. Farmers pumping drainage water (at different levels)

From main drain to marwa (Drain 8)		From secondary drain to IIP (marwa pipe) (W10)	
From secondary drain to marwa (Abu Mostafa)		From secondary drain to individual plot	
From tertiary drain to individual plot		From manhole (subsurface drains) to individual plot	

Figure 19. Farmers pumping groundwater

Well operated by the same mobile pump used for drains		Pump powered by tractor	

3.2.6 Injecting additional water into the distribution network

Another way to complement supply through the use of IPs is to connect them directly to the piped distribution network. Several types of quite remarkable and creative connections have been found (Figure 20):

- connecting IPs to a main pipe of the 'parallel mesqa' type. In a case observed in the Abo Eliwa canal (W10), four sets of pumps were connected to the main pipe at the level of each of the four marwas.

- connecting IPs to the *head of* the main (mesqa) pipe. This can be observed, for example, in the Masharqa canal.
- connecting IPs to the tail *end of the main pipe*, where water abstracted from the drain is injected into the pipe (Manshaqa, Shalma or Mekhezen canals).
- connecting IPs at the *tail end of marwa* pipes, with water pumped from the drain (W10).

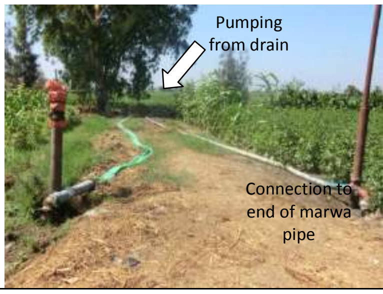
Using such connections demands a degree of coordination with the pump station operator, to make sure that IPs and collective pumps are not operated at the same time, which could create big problems of overpressure and damage to pipes and connections. When the connection is made with a marwa pipe, farmers just need to make sure that the valve at the head of the marwa pipe is closed to operate their pump.

Figure 20. Connection of IPs to the distribution network

Connecting IPs with the head of the main pipe



Connecting IPs from drain to end of marwa pipes

Connecting IPs to the main pipe, through a tower (left), or directly with the pipe (right)



Box 1: Example of increase in pumping capacity/security in Masharqa canal (W10)

An illustration of the pervasiveness of IPs in IIP areas is provided by the Masharqa canal, in the W10 area. This branch canal serves an area of 1700 feddan and has been equipped with 18 collective PS (white &arrows). Despite the fact that in principle all individual pumps should be made redundant and removed after the IIP package is put in place, it can be seen that the area is still has around 200 IPs in place, pumping from the canal and its two sub-branches as well as from the two lateral secondary drains. Note: some of the points indicated on the map below stand for two or even three IPs. (Source: Samir Salama)

Individual Pump(s) Collective Pumping Stations

3.2.7 Other ways of increasing supply

In addition to adapting the infrastructure that farmers have received from IIP and increasing their pumping capacity, they have also several other minor means of increasing supply (Figure 21).

One modification that is made to increase access to canal water is to lower the level of the intake pipe, in case this pipe has been placed too high at the time of construction. This is a quite common source of dissatisfaction among farmers and in some cases (e.g. Mekhezen canal) they have taken the matter in their own hands, excavating the embankment of the canal to lower the position of the pipe. Yet in a majority of cases, farmers are reluctant to do this, partly because of the costs involved but more commonly because they are aware that this is state property and are not comfortable with tampering with it (especially when this implies opening up a ditch in the road). In the IIP project the height of the pipe was calculated based on a hypothetic design longitudinal profile of the canal. In all cases this proved to be too high because expected water levels did not materialize due to the lack of canal re-modeling, radial gates not being operated, and subsequent non-implementation of continuous flow. This problem is ubiquitous in IIP areas and has generated conflicts between farmers and the improvement project, even leading to the abandonment of some stations, as explained earlier. In IIIMP realism has prevailed and automatic gates have been disregarded, while pump intakes are placed at the bottom of the canal.

Figure 21. Ways to increase supply

lowering of intake pipe		Farmers demons-tration	
Leaking gate after being damaged		Perforated gate (Bosees canal)	
The radial gate has been fully removed by farmers (Hasafa canal)		Farmers have installed a bypass around the regulator (Abu Mustafa canal)	
Creating small weirs in the canal to retain water		Creating obstacles in the canal to increase inflow to the pump station	
Creating small weirs in the canal to retain water		Cleaning the mud in front of the inlet pipe	

Other ways to increase supply is to act at the level of the branch canal, and this includes both infrastructure and institutional issues. With regard to hydraulic infrastructure, farmers first try to reduce the negative impact on water flow of the automatic regulators that were put in place to implement continuous flow (see section 3.1). This includes installing bypasses around the gate and in a few cases removing the regulator; blocking the radial gate in the fully open position; and tampering with other sluice gates, damaging the sliding parts or even perforating them, so that it cannot be fully closed and that a minimal flow is maintained. In part, this occurs with explicit or implicit support of irrigation managers.

Although radial gates hinder flow, both because they accumulate garbage and create head loss by narrowing the canal section, farmers are afraid to destroy such ministerial property and as they could be heavily fined for any damage. The radial gate that has been removed at the head of the Hasafa canal is a small one and farmers there were reported to have political influence, with someone in the Shura council or parliament who supported the removal of the gate. Farmers in Abu Mustafa canal hired three minibuses in summer 2013 to go to Kafr el Sheikh Directorate to complain in high fashion about water shortages in general, and the reduction in the flow caused by radial gates in particular. Unable to take the decision to remove a radial gate, irrigation managers constructed a bypass pipe.

Supply can also be increased by connecting the mesqas of a branch canal with other waterways (canals and drains) through siphons, aqueducts and pipes. This is also often implemented by the ministry itself (see IWMI-WMRI report No. 1, 2013). At the micro level, farmers make use of the topography, trying to impound water or raise the water level in the canal by making small weirs with stones or mud, or facilitating the accumulation of trash just downstream of their inlet. They may also de-silt and clean the canal near the inlet of their PS.

At an institutional level, farmers attempt to secure or increase their share of water by negotiating internally (within the branch canal), or complaining to the district engineer or higher authorities about water shortages, to exert pressure in an attempt to increase the water allocated to them.

3.2.8 Adaptation to, and of, the technological package

In most cases, farmers adapt the infrastructure that they have received from IIP. They appropriate the technology for their own purposes. We provide here a few examples.

A very common technological adjustment to the IIP pump station is that farmers have increased the tower with the intention to increase the pressure in the mesqa pipe system and to avoid overflow of water. They have to do this, in particular, when they change their pump engines for more powerful ones.

In the W10 area there are many cases to be observed. In one case, the farmers complain that the capacity of their 2 pumps is not sufficient. As a result in the summer they fight with each other every day on who will irrigate first. The 2 pumps can only be used for the first valves along the piped mesqa, but not for the last valves because the water pressure is very low due to some constriction in the pipe. This is the reason why they have increased the height of the tower.

Farmers also tend to make small adaptations to facilitate the operation of a technology, e.g. to prevent leakage from valves, or to help prime the pumps. Other adaptations are made to the pump houses that accommodate living, security, animals, trees, fodder, etc. Farmers for instance build a quarter on top of the pumping house for a guard to protect the pumps from being stolen. Others build a shed for animals against it, or dry hay or crop residues on top of it. Since these changes do not affect the infrastructure or water consumption and facilitate the life and security of people, they show how such PS are integrated in the life of people

Figure 22. Adaptation of IIP technology

Increase in the height of the tower		Injection of water to prime the pump
		
Use of the pump house for several purposes		
		

3.2.9 On-going project and implementation problems in IIIMP

3.2.9.1 <u>Infrastructure affected by delays in implementation</u>

Because of the delays that IIIMP has experienced, in particular since the Revolution of 2011[5], there were many PS in 2013 which had not yet been completed and transferred to the farmers. In the majority of these cases the pump house and the piping system were put in place, but the pumps/ motors had not been transferred and the electricity was not yet connected to the pump house. Along the Bahr Nemra canal lied a series of such pump stations. Most did not have a pump and in many cases the electricity had not been connected yet. In some cases the stations were connected, but then the electricity cables had been stolen. Sometimes also the piping that connects the station to the pit was gone.

Along the Meet Yazid canal, Bahr Nemra, and El Shoka several pump stations had been constructed more than two years ago, but had not been working ever since, because of the absence of the pumps and an electricity connection. Farmers reported not being informed about when exactly the infrastructure would be completed and given to them.

Delay caused some degeneration of infrastructure because it was not being used: valves had lost their casing or other metal parts and corrosion had taken place. In part, this was a natural process, but theft and destruction by local people or outsiders did not help. The farmer collective or WUA had not been formed or no incentive to come together before the PS was actually in use. This also meant

[5] According to World Bank (2014), "Project implementation has been delayed partly due to: (i) delayed Effectiveness of the loan by one year; (ii) January 25 revolution and ensuing political upheaval; (iii) delays in electrification of small pumping stations; (iv) delayed installation of on-farm subsurface drainage schemes during 2011/2012 cropping seasons because some farmers objected to construction work taking place before harvesting their crops; and (v) shortages in diesel in 2012 and corrugated drainage pipes."

in many cases that the farmers did not feel collectively responsible for the infrastructure and did not protect or maintain it, certainly when they had not signed for it. Because there was no water being distributed yet, farmers were not willing either to pay money for a guard or an operator to protect or maintain the PS. Hence, the delay in the project was both for technical and organizational reasons detrimental to the condition of the infrastructure. The risk was also that this infrastructure that was unfinished will be abandoned, since the loose connection that farmers have felt for this collective infrastructure.

The late delivery of pumps and electricity connections are interconnected issues. The pumps had not been delivered by the contractors. Because they have been made contractually responsible for the pumps until the day of transfer, due to the frequent problem of theft of pumps, the contractors only deliver the pumps at the moment of transfer of the works to the farmers. But this transfer can only occur when the electricity company connects the electricity to the PS. This semi-public company has only a limited capacity to do connections and are also restrained by the overall supply capacity of the Ministry of Energy. So both activities are held up until the definite transfer of the infrastructure.

3.2.9.2 Re-opened mesqas and marwas

Some IIIMP PS have been installed and the mesqa filled in, but the electricity connection has been delayed (see above). In most cases a diesel pump has been installed to bypass the PS and supply the piped network through a special opening in a lateral pipe planned for this purpose (a design innovation of IIIMP pumps, as a result of lessons learned in the IIP project, see Figure 23). This pump has sometimes been provided by IIIMP, and sometimes installed by farmers themselves. Because of this problem but more generally because of the power cuts, there has been a big demand by farmers to include such a lateral diesel pump into the package designed and sold to them. Many of the latest PS constructed now include such a pump which is even, lately, incorporated in an enlarged pump house. In the case of 'parallel mesqas', the former marwas are left open and being used for irrigation.

In other places the mesqa has been re-opened for farmers to irrigate. This can be on the same spot where the mesqa was, but more commonly a few meters away, in parallel with the piping system in the ground, so that the pipe is left untouched. We found places where this had been done by the farmers themselves and others where the IIIMP project did it, in which case a temporary compensation (about 4000 EGP/feddan/year) is paid to farmers in compensation for the land that is excavated.

Figure 23. Consequences of delayed provision of electricity in IIIMP pumps

Reopening of the mesqa, or use of marwa left open		
		
Temporary diesel pump set up by IIIMP in parallel of electric pumps waiting for electricity connection		
		
Damage to infrastructure		
		

4 WUAs and collective action

4.1 Building WUAs and improving infrastructure

4.1.1 WUAs around collective pumps

Egypt has a rich experience with the development of Water User Associations (WUAs) in the field of agriculture. In the past 25 years, many projects have dealt with organizing farmers, improving the coordination between farmers and irrigation managers, and ensuring the participation of all concerned stakeholders. In Meet Yazid this includes different scales: from the tertiary (mesqa), and the secondary (branch-canal) to the district level (around 10 branch canals). This section dwells further on the IIP experience and its lessons in terms of collective action.

Early attention to the potential benefits of better organizing farmers can be traced back to the EWUP Project (EWUP, 1977-84). This research project recommended that farmers' participation should be sought in the field of both irrigation distribution (scheduling, rotations, improved delivery, etc.) and maintenance, protection, and upgrading of physical works (current repairs, mesqa improvements, renovations of branch canals). Since 1996, these different ideas to modernize irrigation were institutionalized by the Irrigation Improvement Sector (IIS) of the ministry. The IIS basically divided the responsibilities for technical and organizational improvements between two separate institutional sections under IIS. Whereas IIP (IIS-IIP) became responsible for the planning and execution of technical improvements, the Irrigation Advisory Service (IAS, or IIS-IAS) was created to spearhead the creation and training of WUAs. As a consequence, the success of each intervention was closely dependent upon each other, but these were coordinated by separate sectors. A direct consequence of the technical options proposed and implemented by IIP was to make the establishment of collective pump-level WUAs necessary. Collective action was needed for operating and maintaining the pump, organizing water distribution, and pay for energy costs. To organize the WUA formation, the IAS called for the establishment of a special well-trained cadre of professionals to define the new responsibilities for farmers and train them to acquire corresponding skills. WUAs were usually established with the signing and receipt of the improvement works and in selected cases received training.

A WUA is defined as "a private organization owned, **controlled and operated by member users** for their benefits in improving water delivery, water use and other organizational efforts related to water for increasing their production possibilities" (IIP, 1990a; Hvidt, 2005). WUAs access water from the branch canal in which, following IIP's design, a continuous supply is to be ensured, instead of the traditional on/off rotation. Continuous flow was the most attractive feature of IIP for farmers, who saw the prospect of a continuous supply and the end to water shortages. They understood continuous flow as "important to assure the success of the project" (Metawie, 2002).

Initially, WUAs at the tertiary (mesqa) level had no legal status, which among other things constrained their ability to levy money and act as independent bodies with full private ownership of the pump-level infrastructure. This changed in 1994 with the modification of the 1984 Law 12, wherein WUAs were defined as legal organizations at the mesqa level in the IIP areas in the old lands. The Bylaws of Law 213/1994 (Decree No 14900 of 1995) detailed the rights and duties of the WUAs, legalizing private WUAs at the mesqa-level and recovery of capital costs of improved irrigation facilities (INECO, 2009).

4.1.2 Branch Canal WUAs and IIIMP

Under the Agricultural Policy Reform Program (APRP) of USAID (1996-2003), a strong support to different kinds of decentralization and Irrigation Management Transfer translated in several policy initiatives and changes. The Ministry of Water Resources and Irrigation (MWRI) promulgated a policy allowing for the formation of secondary-level Branch Canal Water User Associations (BCWUAs) and also for the development of integrated districts. However, branch canal level experiments remained constrained by several factors. The absence of a legal status for user organizations at levels above the mesqa level boundaries made it difficult to develop the financial dimensions of decentralization. The "Revision of Law 12/1984 on Irrigation and Drainage", that was to recognize BCWUAs as user organizations for water management at the secondary canal level and above made it to parliament, but up to present has failed to be passed. Pilot BCWUAs were established under an *ad hoc* ministerial decree. Likewise, the policy of transferring the responsibility to maintain assets such as canals or headworks made it necessary to rehabilitate these infrastructures before turning them over to users, and this required the capacity and willingness of the government to make the corresponding outlays available. Later, this proved to be problematic.

In 1999, the Central Department of Irrigation Advisory Services (CD-IAS) was established as a permanent unit to serve all sectors of MWRI, which became mainly responsible for the creation of secondary-level Branch Canal WUAs (BCWUAs), as part of a broader agenda of institutional reform towards IWRM. The expectation was that these organizations could play an important role in annual planning, maintenance prioritization, water distribution and cost recovery at the Branch Canal. The recommendation was made that continuous flow should be operationalized in the command area prior to improved mesqas coming on line. The BCWUAs could be formed early on, assist in the works on the branch canals, and then later on help in setting up the WUAs at the mesqa level (IRG et al., 1998). We have observed that continuous flow has not been effectuated in the area, which weakened the role of BCWUAs. Nevertheless, several BCWUAs have been created, but not necessarily in the above desired order. Some are active but the majority is dormant, few farmers being aware of the very existence of these BCWUAs. These issues are addressed in much more detail in a companion report (see IWMI-WMRI report 8).

4.1.3 Marwa level

At the marwa levels farmers have always organized themselves. In particular at the time of the 'sakia rings', farmers had to share the use of a marwa. One of the major components of the IIIMP package was on-farm improvement, that included replacing the *marwa* ditches with a pressurized pipe and valve system. These on-farm improvements were combined with organizing farmers of a quaternary canals in marwa committees (Gouda, 2009). However, our review could not establish the existence of any kind of functioning marwa committees. Instead, farmers have their own socially acceptable arrangements at the *marwa* level, which are mostly informal (Dutta, 2013; see also Section 4.5). Although there is thus apparently little scope for setting up formal organizations at this level, the FIMP project, which proposes on-farm improvements interventions, is intended to set up 20,000 marwa committees (see Section 5.7.1).

4.2 WUA formation and construction of collective pumps

4.2.1 The parallel process of WUA formation and construction of pump stations

To zoom in on the process of forming WUAs is useful, as it has shaped how these organizations function in practice and what role they play in the collective action around pump stations. The IAS methodology to form WUAs in the IIP area consisted of 5 to 7 phases (Mott MacDonald, 2008 a, b):

1. Entry: Gain acceptance among (farmer) leaders, select farmer representatives and train them in IIP message & technology

2. Initial Organization: aiming to assist water users on a mesqa to (s)elect their leaders, solve problems and consult with IIP engineers to plan and design the improved mesqa, and explain cost sharing principles. Activities include organizing meetings with farmers, training of councils and the recognition of the WUA. Outputs are the formal organizational structure and registration, the willingness of farmers to organize in WUAs, a discussion and decision of alternative mesqa improvements and the establishment of a mesqa improvement committee. The focus of this phase is on communication about IIP, WUAs and implications for mesqa layout & organization.

3. Preparation for Mesqa improvement: with the objective to involve WUA council/board members in planning, designing and acceptance of the final mesqa design. The activities include a draft proposal, a design meeting between IIP and IAS engineers and the council/board to explain design and possible adaptations and the signing of the map by all in case of agreement. The focus in this phase is on design approval and outputs are several work plans.

4. Participation in Mesqa improvement: directed at preparing WUA membership to monitor improvement activities and solve problems that arise with private constructors. WUA leaders will receive training before turnover and also the pump operator will be trained in O&M after the construction of the improved mesqa and the installment of the pumps. IIP-, IAS engineers and WUA leaders do a walk through the mesqa, before the WUA leaders will approve the turnover with their signatures on an official document. The manuals indicate an active involvement of farmers in design.

5. Regular Operation & Maintenance

(6. Formation of Federations at branch canals)

(7. Continuous monitoring and evaluation)

The latter two stages were originally included, but were later shifted because of several institutional re-organizations. After 1999 the Central Directorate of IAS (CD-IAS) became responsible for BCWUA formation at the secondary level (phase 6). WUA formation for the purpose of irrigation improvement (phase 1 to 5) remained under the special IAS section of IIS (IIS-IAS). Under IIIMP phase 6 became superseded by the BCWUA formation and also Phase 7 became the responsibility of CD-IAS.

During the process of organizing the WUAs (IIS-IAS) and the mesqa improvement (IIS-IIP) a number of documents have to be agreed and signed to form the WUA and transfer the improved works to the responsibility of the farmers. But the above describes the formal procedure of WUA formation and mesqa improvement, which has often differed from the actual procedures followed on the ground. For example, the first 4 phases were estimated to last between 4 and 6, 5 months, but in practice the entire process of WUA organization, construction and reception of the works often took longer: in most cases between 6 months and 2 years. For example, in the case of the Shams el Din PS of 69 feddan at the Daqalt canal the first set of formal documents were signed on the 14th-15th of August of

1999, which concern the meeting of the General Assembly of the WUA, the selection of the board members, the distribution of their tasks and the request for registration of the WUA to the General Directorate of Irrigation. However, the final set of documents that confirm the reception of the pumps, the pipeline and the spare parts, were signed on 15 January 2002, around 2,5 years after the formal initiation of the process. In some extreme cases the entire process did even last more than 10 years or failed to reach a formal turnover of the works. In such cases this extended process may have negatively influenced the collective responsibility that farmers feel for the pump station and its WUA. This delay, however, is only partly due to the time taken to set up the WUAs and more likely reflects the delay in design and construction, problems with the bidding of the work, or farmers not willing to receive the PS.

This and further findings from our survey indicates that the initial conditions for reception of the IIP improvement works were quite varied. Many farmers were receptive to the new IIP package that was offered to them because of the promised continuous flow, cost savings and reduced irrigation times, but there was also a significant portion of the farmers who were not convinced of the advantages of the improvements or who were afraid, uninformed or uncertain about the consequences.

To convince farmers of the benefits of the improvements, some trainings were organized and selected farmer representatives were taken to see examples of IIP pump stations for themselves, although the majority of respondents denied having received any training. What was more effective in persuading farmers to accept IIP improvements was to involve locally influential persons such as local leaders, agricultural cooperative staff, government officials, big land owners, family members or educated people in favor of the project who farmers would trust and respect. Such strategies to convince farmers were especially needed when farmers opposed the project, because they already had direct access to water from the canals or the drains and would gain relatively little from the collective infrastructure. In case these farmers were not really convinced by the project improvements, and the pump capacity or network pressure of the PS did not win them over, they were often the first to use their IPs again to add water according to their field requirements. When farmers were adamant to refuse and delay the signing for receiving the infrastructure, they were sometimes able to negotiate via the contractor for larger pump capacity in their PS, or an increased number of valves on the pressurized network. A last tactic that was commonly used to proceed with the mesqa improvement further on in the process, was to have other less informed water users sign for the reception of the works.

In principle, the choice for accepting the improvements was a free choice for the farmers, in that they could also refuse. About a third of all the respondents confirmed to have indeed have had the possibility to refuse the pump station, often illustrating this by examples of farmers who refused and do not have a pump station now, in some cases to their regret later on. Some examples from different PS:

> From the beginning they agreed. There was no refusal, even after having noticed some defects they still agree for two reasons: 1. IIP covered the open mesqa and put a pipeline, which improved the accessibility of the land. 2. Reducing human effort, before *tatweer* they irrigated rice (pre-irrigation) 8 hours and now only 3 hours per feddan, so most people have done away with their IPs.
>
> The farmers immediately had a good feeling about IIP, so they were willing and there was no rejection of the improvement. The engineers told them from the beginning that they would install a PS with 2 diesel pumps. They had the feeling that they had the choice to refuse the PS. Also because on the other side of the canal there is a pump sump, who refused to get a PS.

> At this PS they were convinced, because IAS was promising continuous flow and less effort in irrigation. The canal was in a bad condition and the shortage of water from the intake was the big problem. They did have the choice to refuse, but they were convinced because of the advantages explained to them.

About another third gave no clear yes/no answer to the question of whether they could refuse, also possibly because they were divided amongst themselves about the improvements. However, more than a third of respondents indicated that they did not have the choice to refuse the pump station. In these cases farmers indicate that there was significant pressure exerted to accept the improvements. For example, one farmer stated that "before, under Mubarak, it was difficult to refuse government programs, but this has changed after the Revolution of 2011". During implementation (under Mubarak), an early IIP Director often stated that IIP is a 'national project', implying that it was obligatory and there was no choice to refuse. In some cases the police enforce implementation:

> "It was an obligation. The police took several farmers to jail 1 or 2 days to threaten the others, so they accepted. They stated this is a 'national project', you cannot stop it. Accept it or not but it will go on. To protect the delta and avoid sea water intrusion, the project will start in this region (W10) and then spread over the whole delta. It is obligatory. Even the powerful people in the village who wanted to stop it and went to talk to higher governmental levels, could not stop it, so let alone the small farmers. The people who objected accepted it in the end.
>
> If you would object they could arrest you and you would go to jail. The police would get involved, so it was obligatory."

A significant number of cases indicate that pressure was used by the government (IIP, IAS, cooperatives, etc.) to persuade farmers to cooperate with the promoted improvements and establish a WUA. This top-down orientation of project implementation was in line with the nature of the political regime at the time.

An unfortunate example was recorded in El Mekhezen, a tail canal of the MYC:

> "In 2000 IIP started constructing the PS and the contractors took 2 years. But the farmers did not sign nor use the PS. IIP kept reminding them that they had to sign, but they were not convinced. After the contractors finished (2002), IIP asked them to receive, but the farmers predicted that they would face many problems and conflicts about the scheduling, so they rejected to receive. They visited the IIP office in Kafr El Sheikh many times, where engineers tried to negotiate but they did not sign. They resisted for 2 years. Then the IIP delivered the papers to the agricultural cooperative they belong to, from which they receive fertilizers, pesticides and other services. There was a formal memorandum between the MWRI-IIP and the Ministry of Agriculture for this purpose. This cooperative asked them many times to sign. 'Be sure', they said, 'This is a National Progamme'. Do not to try to escape, now or later you will sign. Some big land owners also pushed the smaller farmers: If you will not sign I will sign. 'Be wise and sign'. Finally they yielded and signed in 2005. One month after reception both pump motors were stolen."

A similar event was described by several farmers in an IIP area outside of the Meet Yazid area, also visited by the team (Bahr el Nur). Some farmers refused the project despite being told this was a national (compulsory) project, and the police was eventually asked to intervene. Several farmers were taken to the police station and only released when they would sign a document stating they would not obstruct the project (see IWMI-WMRI report 8).

In yet another canal most farmers were against the project and refused from the beginning. One employee of department for Religious affairs (*Awqaf*), who was familiar with the engineers and government officials, helped to convince farmers, in particular those who had land far from the canal and could benefit from a collective PS. He also explained that the project would go ahead regardless of their approval and that they should be positive about it and look for benefits for them (see IWMI-WMRI report 8).

In one of the canals of W10, implementation faced very determined farmers who had a lot of suspicion about and opposition against the project. There were stories that this was an American project and people even thought that an American company would come and start to sell the water to the farmers, so they refused and did not allow the staff to go into the field. This shows how perceptions can be influenced by suspicion and the lack of adequate communication. Easing the issue involved the intervention of a sociologist (who had been hired to improve communication with farmers), as well as the police.

4.2.2 Project implementation and the formation of WUAs

During project implementation, IAS and IIP worked in parallel to register WUAs and improve mesqas. Farmers' observations about this process may help to explain the rather loose connection that many farmers seem to feel with the formal WUA and sometimes with the collective infrastructure:

1. The IAS/IIP staff in at least a third of the reviewed cases made a pre-selection of known and trusted farmer leaders to prepare the selection of WUA board members. In other cases, the candidates for the board were nominated by a small group and ratified by the rest of the farmers and the IAS/IIP staff. These often tended to be the larger and influential farmers and represented the major families in the projected area, who could be considered as local opinion leaders and helped to convince other farmers to accept the improvements. This contributed to the acceptance of the infrastructural improvements but not necessarily to the sustainability of the WUAs. An example:

> "Board members were selected initially by the engineer and some large landowning families. Since then, the members have not been changed. The WUA member should be rich with a large area, and should be a known and respected figure of the society".

2. The design of the pump station and the pipe-network with valves has been the work of IIP engineers and the participation of farmers seems to have been fairly limited. In some cases this led to impractical design, such as too large areas with a limited pumping capacity, the conflating of land from different mesqas, conflicting families, private land owners (*milk*) and agrarian reform farmers (islah), with too few valves, a too low pump intake, etc. This however does not mean that farmer's preferences did not influence design at all, since some farmers were effective in posing their demands in exchange for accepting the works.

That the involvement of farmers in the design affected the acceptance of the pump-network design and thus the basis for collective action becomes clear from the following example from Bosees, described on the basis of farmer accounts:

> Most farmers in this PS are far from the government, they deal with the government with suspicion and they are afraid of its authority to force them to do something. So they agreed with the improvement because they were afraid. They thought they did not have an option, but later they found out that they had and that their lack of choice was imagined. IIP constructed a big new PS for 70 feddan in 2000, which was too big for them. After some time they became more familiar with the engineers. This is when they felt confident enough to refuse signing for the reception and forming a WUA. So they never used that big

PS. However, they continued to talk with the IIP engineers and finally after some years they agreed that the PS would be split into two pump stations of roughly the same size (35 feddan). The construction took a year and started 5 years ago. The PS was taken in function, signed and formed a WUA four years ago. To receive a PS you have to have a WUA. The board members people were selected by engineers, but elected by the farmers. Both the PS and the WUA board are working without problems.

Many counter-examples can be given, whereby requests by farmers were not considered, such as some stations in Mares el Gamal, where farmers wanted the main pipe to be extended so as to have valves covering the downstream part of their area. The contractor said this was not possible and applied the design with valves barely reaching mid-distance, meaning that farmers still have to use long marwas and to wait half an hour for the water to reach their field, which defeats one of the main objectives of the project.

3. Because of the complexity and duration of the procedures, it was not always the same people who accepted to form a WUA (with IAS) and those people who signed for agreement and reception of the improvements (with IIP). This gave room to a pragmatic focus on getting the signatures rather than on achieving a broad acceptance among the farmers.

4. Few farmers (<15%) confirm that the WUA received training from the IAS. The majority of the interviewees state that they received no training. Only a few WUA board members confirmed to have received training on how to establish a WUA, schedule irrigation, calculate and collect fees, and operate the pump station. In the absence of effective training to a wider population of water users, farmers deal with tasks such as irrigation scheduling, pump operation and maintenance, fee collection, conflict resolution with locally available knowledge, experience and ways of doing things. Farmers do manage many of such tasks without major problems but they lack externally authorized expertise or standard forms of irrigation scheduling. Often, training on how to operate the pump was limited to the contractor giving advice and showing basic principles just before the reception of the PS.

Few water users were able to distinguish between the different and parallel roles of IAS and IIP in the technological improvement and WUA formation. In most cases they have not built long-term relations with the different engineers from these departments, which was impossible given the large number of PS they were servicing. The coming and going of different groups of engineers was relatively unpredictable for water users and it was therefore not always possible to discuss problems or indicate concerns concerning the new pump station. Very few farmers have indicated awareness of ongoing monitoring and evaluation of the improvement efforts and the possibility of giving feedback on the way improvement was carried out.

5. Most farmers consider not the farmers or water users as the WUA members, but the five board members. A WUA board usually consists of 5 members (60%): Chairman (president), a deputy, a treasurer (*amin sunduq*), secretary and one ordinary member. Around 20% the WUA boards consists of less or more members (between 2 and 10). All of these functions are carried out by men, as is common in the Egyptian public domain. Theoretically these 5 members were to be elected by a general assembly consisting of all land owning farmers in the PS for a period of 4 years. However, after the very first meeting to register the WUA with the help of the IAS, usually no other formal meetings of that body have taken place. The consequence is that the board often does not get re-elected or renewed. New members are not elected but merely designated during informal meetings. Around 50% of the researched cases the board had not been changed since the registration of the WUA, but in more than 20% the board members were replaced. Some striking answers to the question if board members were changed:

"Yes, every 2 and a half years. Those who travelled or died or were not active were usually changed".

"No. Even those who died or moved away have not been replaced". The WUA is not seen as a necessary institution, the farmers rather rely on an informal group of influential men.

"No. The *rabta* (WUA) is on paper. Abdelrahman collects the expenditure, but he is not the treasurer…".

"When one person dies or is not performing well, we collectively decide to replace him; the money collector was very kind but we found a gap in the budget and he had to sell a buffalo to reimburse! The president is useless; the first one died".

In the latter case farmers at a PS knew how to register a change in the WUA board at IIP, but in many other cases they had no idea, since trainings were usually only directed towards board members. That such a large number of WUAs have not renewed their board membership indicates that this is not so crucial for the everyday management of the PS.

More than 75% of the interviewed water users consider only the board members as a "member" of the WUA. They do not see themselves as members, although they are actively using water and contribute money to buying a new pump or pay an operator. They may see themselves as beneficiaries (*muntafeen*), but not as "members", that is members of the WUA board; a group of generally 5 persons. The WUA also does not include the renters and sharecroppers but only the land owners, which excludes a significant share of the fee-paying irrigators in a PS. Female water users are also not represented by women in the WUA boards, as in many other rural organizations. The ideas of farmers about WUAs are often associated with how they think about *tatweer*, how it was implemented and whether the technical package is working given the conditions of water availability. Therefore, the connection that famers feel towards the WUA (board) is often weak.

6. Formal WUAs are often not or only party active. Of the almost 50 WUAs under review not many WUAs are active organizations that coordinate the collective action required by the mesqa improvement. The number of WUAs that are functioning on the whole as a "sustainable self reliant WUA which is fully owned, controlled and operated by the farmers for their benefits to be achieved by improved production possibilities" (Mott MacDonald, 2008b: E3) is very limited.

Earlier assessments of participatory water management (APP, 2007) have already revealed worrying trends concerning farmer participation in WUAs. Barakat concluded that (i) Participation of WUOs in water management is extremely low, (ii) all actors have a poor understanding of the possibilities to take action, (iii) WUOs and MWRI field staff don't feel partners, (iv) there is a felt need of clear instructions from higher levels. Likewise, Bron (APP, 2007), based on the monitoring and evaluation of 150 WUOs during several years, concluded that: "1. The level of participation of water users in water management, also when organized in water users' organizations, is very low. Even the level of being informed after MWRI field staff has taken a decision often is not reached. 2. No water users' organization in Egypt has reached a level of institutional strength that can be considered sustainable. 3. Projects achieve an initial build-up of the institutional strength of WUOs. However, apparently the projects are not successful in reaching a sustainable level of WUOs strength. When the attention for the WUOs decreases after the completion of projects, the WUOs' sustainability level declines".

7. Substantial discrepancies exist between the legal structure and normative ideal of WUAs and the actual functioning of organizational arrangements on the ground. Here are a few illustrations of this gap, whereby articles of the law are compared with actual practices (PACER Consultants, 1995):

"The General Assembly is to convene once a year within three months from the end of the fiscal year of the association to discuss the balance sheet, final accounts, the annual report of the association council, election of members of association councils and any other issues proposed by the association council listed in the agenda of the meeting" (Art 17) [There is no such thing as a regular General Assembly];

"The General Assembly shall convene according to an invitation directed form the Sheikh of Mesqa, one third of members who own not less than 30% of the association land or upon the request of the Water Guidance Engineer"… "The invitation shall be delivered by hand to the association members or the representatives, who will sign a copy of the invitation 3 days prior to the convention of the General Assembly" [There is no formal invitation; farmers meet based on requirements with no minimum quota rule].

"The General Assembly in its first convention and then every two years shall directly elect five members to form an association board" (Art 21) [No regular elections are held, only sometimes board members are replaced in case of death or when they do not function].

"The Association's board of directors shall meet once per month at least according to an invitation form" (Art 24); "Organizing the monthly regular meetings to review the programs of operation and maintenance of irrigation canal and pumps, and studying the financial position of the association budget and its account in the bank. Placing a time table for water rotation between irrigation canals or taps connected to the irrigation canals according to the areas belonging to members, identifying the kind of crops, and reviewing these time tables on monthly basis to be amended" (Art 23) [Meetings are ad-hoc and water distribution arrangements tailored to local conditions without written tables].

"The IIP project had a communication component intended to "strengthen awareness of project benefits, including water conservation and environmental issues and train them in the operation and maintenance of mesqa and financial management" (…) "WUGs would be organized for each tertiary block (mesqa). Although dictated by law, these groups will be established through *dialogue, persuasion and agreement* of at least 80 percent of the beneficiaries" (World Bank, 1994; emphasis added). [There is little evidence that the rule of the 80% has been adhered to. In many cases "reception of the works" has consisted in having two or three influential persons signing the document. It also did not appear that training in water management, maintenance, and financial issues were as prominent as indicated in the project document].

Both the Law and the IIP project had established very high levels of expectation regarding the way WUAs would implement water distribution. The Irrigation and Drainage Law 213/1994, describes the many responsibilities ascribed to the WUA president (Mesqa Sheikh) (Articles 49 and 50, in Gouda, 2009), such as selecting "the key-persons to be in charge of those valves on the mesqa or those marwas opposing each valve or gate from among farmers of these marwas and determining their responsibilities", working out "irrigation schedules between the marwa outlets or those valves connected to the marwas according to members' field areas and type of crops as well as reviewing these irrigation turns on a monthly basis to enable any amendments"; "taking the appropriate decision … to settle any possible disputes among farmers on any marwa", tasks that are more often than not undertaken collectively or by individuals others than the WUA president.

8. Although formal WUAs are not active as planned, farmers are nevertheless organizing themselves individually as well as collectively, formally and informally to manage the pump station, finance improvements and solve conflicts. It should be no surprise that formal organizations created on paper, do not necessarily endure as planned, but organizational arrangements nevertheless get

adapted and collective action persists informally at different levels. The President of the Association is often not as active as expected and does not interfere much with the daily management, most of the work generally being done by the pump operator. The treasurer may collect the fees, but it is sometimes also the operator, another board member or respected farmer who does so. Decisions are generally taken not in a formal context, but by gathering a few influential men around the pump station or for example after Friday's prayer. Several farmers claim they do not need a WUA and manage water distribution amongst themselves at the pump level, as well as taking care of maintenance and other needs. Hence, most working pump stations are managed collectively in a quite informal way, remote from the original ideal-type. The question is if, when and for whom this is a problem.

As indicated before, the absence of an active WUA as an organization, does not necessarily mean that no collective action takes place, decisions are made, or leadership is exercised. Take this example from the tail of a branch from Daqalt canal:

> "There is no formal WUA here, since nobody signed for the reception of the pump station. There was no registration, because they did not want the PS. But because they had to start paying (imprisonment of one man), the PS is now considered theirs. They thus started arranging things amongst themselves. Because 'everybody is family here' there is no need for an association. Anybody can collect money in cooperation with the operator and without having the position of treasurer. The treasurer (a former army man) oversees the process as a leader and appears to do a lot."

At crucial moments in the management of a PS, we observe that water users often have informal ways of meeting, consulting important men and families and deciding on a course of action. This can be for example when a motor is stolen and needs replacement, extra fees need to be collected, or a switch from a diesel– to electricity pump is occurring. Such decision making often takes place informally: "we meet after the prayer on Friday and decide between ourselves".

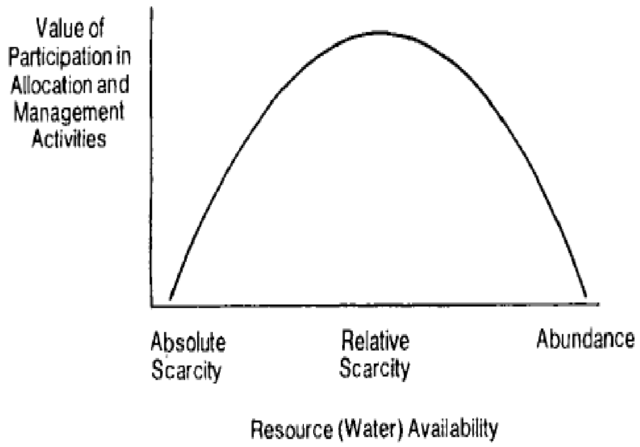
Collective action and cohesion around a PS is possible through a mixture of formally and informally recognized sources of authority and leadership. Although the registered WUA board as a whole may not be active any longer, still one or two of those original board members may be active and recognized in the pump management. In addition, other respected people acquired new leadership roles with regard to the PS. In many cases, their authority is based on internal sources of legitimacy (relation with the main families, landownership, wealth, expertise), or external forms of legitimacy in local organizations and institutions, such as the mosque, the cooperative, the *omda* (local mayor), the ministry of water or the governorate. Hence, the leadership and collective action that is required for the management of a PS does not depend on the registration or working of a WUA board. The latter is primarily a requirement of the project and of the government. IIP and IAS engineers are quite pragmatic about this situation in the field and simply deal with the operator or the leader figures, as identified on the spot by local people.

What the board members of the WUA actually do is highly variable and often less well defined. An important function regarding the PS is that of the treasurer who is responsible for the financial management of the PS. For the chairman or president of the WUA it is often less clear what regular tasks he has, besides being perceived as the maximum authority of the WUA. Again this varies per case, because there are cases where the chairman does really do most tasks himself, but more in general the chairmen seem to stand at some distance of the daily management. Nevertheless, the role of the chairman and the board in conflict resolution is more widely recognized.

4.3 Water distribution at the pump station level

Robert Wade (1988) proposed a curve to relate water scarcity and collective action, which was later adapted by Uphoff et al. (1990) (see Figure 24). Collective action increases from a situation of water abundance to relative water scarcity, but then decreases again when approaching absolute water scarcity. When we view irrigation scheduling as the prime expression of collective action around a PS, what are the conditions under which it exactly emerges? With water abundantly available there is relatively little need for scheduling, the need increases to an optimum with relative water scarcity, but the collective interest in scheduling might decrease again and finally collapse when water scarcity grows to extremes. Hence, the need for irrigation scheduling to avoid conflicts is highest in the middle and at the top of the curve (relative water scarcity), but decreases when approaching absolute water scarcity as tension rises and mechanisms to 'share' such a level of scarcity are impossible to maintain.

Figure 24. Curve depicting the relation between collective action and water scarcity (Uphoff et al., 1990)



The following quotes show that scheduling usually occurs to avoid conflict in summer with relative water scarcity and that it needs to be instated by an operator or authorised by local leaders.

"The schedule is made by the farmers from the mesqa themselves. It is not written down anywhere, but farmers are all very much aware of when it is their turn to irrigate. Initially, there was no schedule regulating water use. The pump station had been installed just before the winter, when water was plenty, and farmers felt no need for a schedule. When the summer season started and water became scarce and demands high, the schedule was put in place to prevent conflicts between farmers. Even now, the schedule is only effective from April to September, after which it changes to an on-request system" (see de Bont, 2013).

"Many times conflicts occur around the scheduling, because everybody wants to irrigate first. This is usually solved by the operator and sometimes with some help of [a local leader]".

This scheduling dynamic can be observed at the level of an annual cycle. As water demand increases drastically during May and June during the critical period of rice transplantation, the supply-demand ratio of the PS drops. This is when a schedule is called into life. In some PS, water supply in early years was rather abundant and there was no need to establish a schedule; but this need came to be felt some years later, as a drop in supply or an increase in water demand due to rice expansion, was experienced.

Yet, although a solution to manage conflicts in the PS, irrigation scheduling under increasing scarcity and a lower supply-demand ratio may itself become the focus of conflicts among farmers. This explains why some water users claimed that the conflicts had increased because of collective pumping (from a situation of unregulated individual pumping), while others claimed that the irrigation schedule had reduced the conflicts (that would have occurred without the arrangement).

In a general continuum from relative water abundance to extreme scarcity in the summer period one sees different degrees of conflict around the scheduling:

- Water Abundance: On the head of Daqalt, a generally well-supplied canal (5 'on' days), there is no conflict among the farmers about the internal distribution because they generally have sufficient water. The irrigation schedule they have adopted is that the first 3 of the 6 valves (1, 2, 3) irrigate on Saturday, Monday and Wednesday, whilst the last 3 valves (4,5,6) irrigate on Sunday, Tuesday and Thursday.
- Relative scarcity: Halfway the long Bosees canal a middle-sized PS (50 feddan) receives only around 2 on-days of water. The farmers acknowledge: "yes, when there is shortage of water everyone wants to irrigate first, but we usually sit together and solve it".
- Absolute scarcity: In the tail area of Meet Yazid (W10), in the troubled middle section of the Safan canal, a large PS of 105 feddan receives 2-3 on-days, which is very insufficient given its size and the fact that only 2 electrical pumps can be operated at the same time. So many conflicts occur during the water short period. Some are solved locally, some by the board and if they cannot, sometimes the police might be involved. Both water availability (biggest problem) and the capacity of the PS are the reasons behind conflicts. They open the four valves that serve 25 feddan together to irrigate with a very low pressure. The problem is that farmers are not patient at all and they all want to irrigate at the same time.
- Absolute scarcity: A case were the irrigation scheduling became so conflictive that farmers collectively decided to replace the pump-network by a deep buried pipe is situated at the middle of Mekhezen canal in the tail of Meet Yazid (see also section 3.2.1.4). In this case farmers had long refused the reception of the PS since they feared facing many problems around the scheduling. Additional problems were that they had many renters in the area who were less committed to the scheduling. Also the refilling of the diesel of the collective pumps was problematic.

Besides depending on water scarcity as an independent contextual variable, collective action is also mediated by the technology that provides access to water. Irrigation scheduling is a response to farmers' collective dependence upon a pump network with a restricted supply capacity through which water is allocated per (equal) time share. Although the need to establish rules for irrigation scheduling as a solution to limited water availability is normally hardly contested, the specific implementation, timing and order, may generate conflict.

Where technology also plays a major role in facilitating collective action, irrigation scheduling and reducing conflict, is in the many ways that farmers inject additional water into the pump-network (see section 3.2.6). Expanding the total supply capacity by adding private pumps at the canal or drain, reduces the dependence on the PS and thus the level of conflict over scheduling. When a farmer has another source of water that he can manage independently, the risk is lower that he will engage in conflict over the water from the PS. For example, there are some conflicts regarding the sharing of water across different valves. Sometimes, farmers open their hydrants out of turn, and this causes conflicts. But it is a not a major issue. Farmers also pump directly from the drain and this avoids conflicts over the collective irrigation schedule.

The pump operator is responsible for water distribution in at least 80 percent of the surveyed pump stations. Only in a minority of cases there is no operator at a PS and pump operation is done by a board member or amongst the farmers themselves. Unlike the more prestigious board positions which are not remunerated, the position of operator does not bring status, but in most cases it is paid. The wage varies widely (between 40 to 400 EGP/month), but is much below the minimum wage. In some cases the operator is paid in kilos of rice by the farmers to sustain his family. As a result, the operators are often landless laborers or small farmers and they are invariably men.

The operator is responsible for operating and maintaining the pumps in the pump station and (to a lesser extent) enforcing the scheduling of irrigation at the mesqa level, which means supervising the opening of the valves according to schedule. In more than a quarter of the PS, the operator also plays a role in collecting the fees. He is usually also involved in conflict resolution (see section 4.7). Because of his central role in the life of the PS the operator is also a central source of information about who is doing what, where the water is and what other news there is in the area.

When an operator is in charge of the pump station, he keeps the keys of the steel door which is locked when the pumps are off, given the high risks of theft. In most cases this means that he has to be present to put on the pumps, which is sometimes problematic when he has other occupations. When the operator is absent, he might share a copy with a board member or a trusted figure who lives nearby. In one case, the area was divided between 4 valves and sub-areas and each of the 4 group had a key. In a few PS, they are more relaxed and the key is passed on between farmers, can be found on the windowsill, or is left with the nearby shopkeeper. In the low season the operator might switch on the motor for a farmer who wants to irrigate and ask him to return the key after being finished. In other cases the operator might ask his wife, a brother or an older child to put on the pump when he is away.

Since a rotational system is applied at the branch canals and in some cases also within a BC, operators have to be aware when the on-period arrives for his PS, depending on its position along the canal. During the on-period he will need to operate the pumps for farmers to irrigate. The summer is the most critical period for water in which in many cases an irrigation schedule is used as discussed above, whereas the winter is usually less hectic and water supply is sufficient and water demand more flexible. The specific period of peak water demand is during the period of rice transplanting (May-June) for which a lot of water is required. During pre-irrigation period (land preparation, compacting, and replanting of the rice seedlings from the nursery), the bordered fields are flooded with a significant water layer, which may require 3 to 6 hours per feddan to fill. In comparison, the regular rice irrigations take 1-2 hours per feddan. Because many people want to transplant around the same time, this is a time of almost constant operation of the PS and the operator.

For example, in the middle of the Mekhezen canal on the tail of Meet Yazid, a PS has an on-period of 2 to 3 days (48-72 hours) in this critical period. Of the 90 feddan, around 60% is rice, and it would take around 180 hours to establish the rice (pre-irrigation: 3 h/f), which means that their planting is staggered, taking at least 3 on-periods. This implies a pressure on the operator and the PS, because all farmers want to transplant in time.

During this key period of transplanting, pump stations are operated at their maximum capacity and often almost continuously, i.e. for 24 hours a day. Those who can afford it because of sufficient water availability, or are forced because the protection against overheating has switched the pump off, do let the pumps cool down for some time. Those operators who have 3 pumps at their disposal can alternatively use 2 pumps and spare 1 so that it has time to cool down and does not break. However, others are under pressure to operate the pumps for 24 hours without interruption, a few days in a row, in order to finish transplanting as long as water is available. Even though the operators know about the negative effect of overheating, they feel they have no choice. This may result in higher maintenance expenses. Of course, these problems are worse because of the lack of effective restrictions on rice cultivation.

Likewise, night irrigation is mostly practiced in this period at the beginning of the rice season, since the night may be the only time that farmers can irrigate. Towards the tail of branch canals there is a higher need to irrigate at night when the number of on-days is severely limited. In the winter the incidence of night irrigation is much less frequent than in the summer, because of the water adequacy during the day. Besides water scarcity at day time, another motivation to irrigate at night might be the fact that a farmer has a day job and therefore can only irrigate at night.

In the winter because of the reduced number of pumping hours, the branch canals will fill up more quickly and their storage capacity is used to a larger extent.

Additional data shed light on the time of pumping operations. As illustrated by Figure 25, which shows results for a pump in Bashair branch canal, farmers preferably start pumping early in the morning as well as in late afternoon. Pumping early in the morning suits farmer because of the heat but also because the limited number of pumping during the night results in water being stored in the canal, and therefore higher levels in the morning.

An interesting issue is that of the duration of pumping events. The time to irrigate one hectare depends – among other things– on the type of crops, the initial soil moisture, and on how many valves are open at the same time. In general irrigation of the plots takes one to a few hours, which leads to the expectation that pump operations would in general last a few hours. As illustrated by Figure 26 (for PS B6b in Bashair BC), the majority of pumping operations last less than one hour, with a very large proportion lasting less than five minutes (45% in that particular case). This vividly shows the problems of water availability in the canal and the high frequency of cases where farmers attempt to pump residual water to the last drop. When attempting to do so they are forced to discontinue pumping after a few minutes to avoid pump cavitation (air being sucked up instead of water). Pumping in the middle of the night is clearly associated with pressing needs. The month of May, which corresponds to the transplanting of rice, distinguishes itself by 15 pump operations between 2 and 3 o'clock in the early morning.

Figure 25. Hour in which pumping operations start

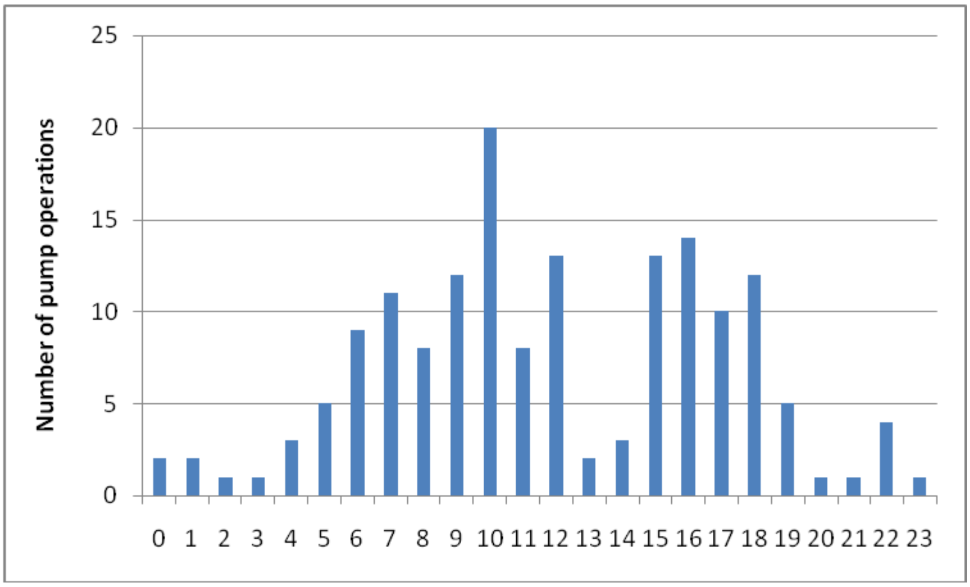
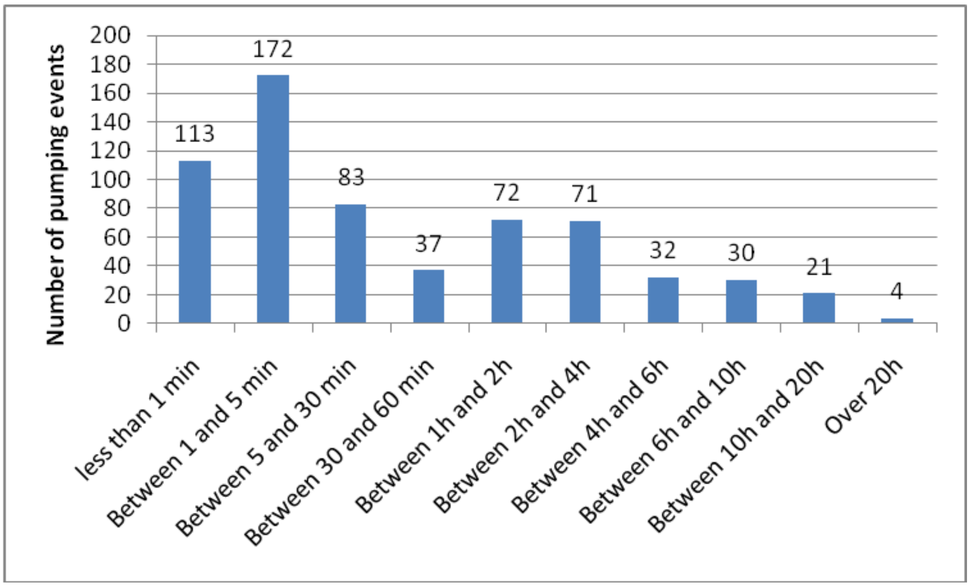


Figure 26. Distribution of pump operation durations (B6b)



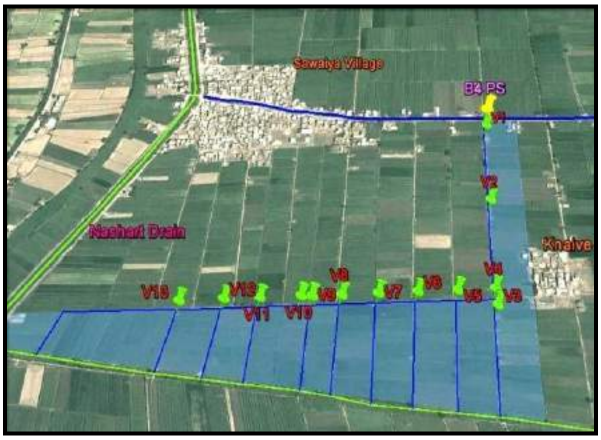
4.4 Water distribution at the mesqa/valve level

In the majority of pump stations, the operator follows an irrigation schedule during the most critical irrigation period of the summer (May, June, July) which varies per station. The schedule typically divides the service area of a PS in two to four parts and rotates the water between them in an order that is repeated afterwards. Each of these parts receives pressurized water for a number of hours, often half a day or one day. These parts consist of a segment or branch of the main pipe, a number of valves, or a marwa. Irrigation schedules are usually simple and straightforward as they mostly take in account the irrigated area and the expected number of on-days. Several examples of irrigation schedules are included to clarify their structure:

- 24h for the upstream reach and 24h for the downstream reach; in each reach the first inlet starts; and the next rotation will start from the end
- When they have water for 3 days, they will give 1 day per valve (3). When they only have 1 day they will divide it in 8 hours per valve
- The land is divided into 3 parts (30 feddan each), 1 day for each 30 feddan and each feddan have half an hour; in addition they irrigate from the drain. Who irrigated last starts first next time
- The 96 feddan divide into 2 (right and left) and each can have 12h; the one irrigating last starts to irrigate the next rotation
- A 54 feddan PS has four marwas, each should have 24h, so they rotate for 4 days to irrigate the whole area.

- The 52 feddan of the mesqa are divided in two equal parts of 26 feddan. One half irrigates odd days, the other even days, making it easy to remember whose turn it is after water disappears for a longer time. The halves are again divided in quarters of 13 feddan, but fields in one quarter are not clustered. They are spread over the mesqa and served by different valves. Each quarter gets 12 hours, resulting in 55 minutes per feddan. However, several valves open at the same time, which means that a feddan gets a smaller flow, but more time. If four valves open for instance, a field receives four times 55 minutes (equaling 3 hours and 40 minutes)(De Bont, 2013).
- At PS B4, in W-10, the system is demand driven until rice transplantation. Then the following rotation is used: There are 13 main valves and 109 farm hydrants which cover an area of 72 feddan (see Figure 27). Four main valves on a row are opened sequentially during a period of 24 hours and then the next four valves, and the sequence is repeated after every three days. The farm hydrants along one given *marwa* pipe are also opened sequentially, and the irrigation starts alternatively from the beginning and the end of the *marwa* respectively, for each irrigation cycle (Dutta, 2013).

Figure 27. Layout of PS B4 in W 10 area



- Each feddan gets 40 minutes of full-flow irrigation and 80 minutes when two valves and two pumps are open, which is the norm (if they would open less than two valves, the pressure would be too high; if they would open more, the flow would be too low). The first half and the second half of the mesqa irrigate on alternate days. Day and night irrigation switch between the left and the right side: if you were the first to irrigate in the morning last time, you are last in the night next time. Turns continue, even if there is no water (a straightforward but sometimes unfair way of dealing with interruption in supply). At valve level, the same principle of changing orders applies: the farmer who is first to irrigate this time, will not be first next time. All monitoring is done by the farmers themselves (see de Bont, 2013).

- 12 valves are ideally distributed in 3 blocks of 4 valves that get a certain number of hours. But in reality there is no fixed scheduling and this creates problems during the summer. A partial solution is to use drainage water although the quality is low.

The rotation between farmers at the plot level can be modified depending on particular circumstances. For example, certain crops may receive priority, for example vegetables or rice in urgent need of water, since other crops like cotton are more tolerant to shortage. Single women or widows may see their term defined in a way that they do not have to irrigate at night. In a PS of Abu Mustafa one feddan has been given to the community (waqf) after the death of a rich farmer, with the production donated to poor people. This plot was seen as having priority and farmers even paid for a new valve to be constructed which would solely deliver water to this field (de Bont, 2013).

As the last example shows, there are pump stations where a theoretical schedule exists, but is not really enforced. This can be because the farmers did not agree about a schedule, nobody is authorized to enforce it, or it simply creates too many conflicts during the critical period, because all farmers want to irrigate within a (too) short available time. In such cases of water scarcity farmers are likely to install individual pumps at a drain or canal for additional irrigation, in order not to depend exclusively on the collective pump network. When some farmers only depend on their individual pumps this may lead to a fragmentation of the PS (see section 3.2.4). In contrast, situations with abundant water also do not require a schedule and the operator distributes the water on-demand. Dependent on the water availability and pump capacity in different parts of Meet Yazid, the available number of hours to irrigate a feddan varies widely per schedule, between half an hour to two hours, exceptionally three.

Before and after the summer, the most critical period in terms of inadequate water supply, there is normally less of a problem of inadequate water supply in large parts of Meet Yazid. So, most pump stations relax the irrigation schedule and shift to a demand-based system of 'first come, first served' in which the operator starts the pump on request.

Irrigation schedules are thus adopted under conditions of relative scarcity. Initially, pump stations do not necessarily have a schedule but are forced to adopt one when the irrigation demand starts to exceed the supply (as observed in a series of new IIIMP stations in Bashair/Mares el Gamal). Ideas for a schedule can originate from the WUA board, influential or large farmers, the operator or from a contractor who installed the PS. Although in most cases it is the operator who assumes responsibility for enforcing the schedule, his authority might not always suffice in stressful conditions and he requires the authority from a board member or influential local leader to apply a schedule. In some cases it is not clear who is supposed to enforce the schedule, which might generate conflict.

The number of valves that the operator can open at the same time is usually one or sometimes two valves per pump (several pumps can be operated at the same time). This number depends on the pressure in the pipe network, associated with the number of working pumps, their capacity (60 or 90 l/s (sometimes 150 l/s), and the total area that the pipe network services. So the PS B4 (example used before; Figure 27) irrigates 72 feddan with 13 valves (3 electrical pumps):

> One valve is opened at a time, and under special circumstances, two valves are opened at the same time. The time of opening depends on the area under the valve, and the need to irrigate. Some valves might be opened only for 3 hours if only 3 feddans have to be irrigated. Also, the farmers often share the water time. So, each valve might not be opened for six hours (might be more or less).

Indeed, the area that every valve serves varies greatly, which determines how long it can be opened for one irrigation turn. Each valve services an area varying between 3 to 15 feddan, on average around 9 feddan, but there are extreme cases of valves serving more than 30 feddan.

Only under special conditions will the operator open more than 2 valves, such as with insufficient water availability and low pressure in the system. For example, a large pump station in the tail of Meet Yazid in summer has to irrigate 105 feddan with 3 electrical pumps and 17 valves in an on-period of 2 to 3 days. When they have 2 pumps working – 7 valves are opened at the same time.

Other exceptions, however, have been observed. A mesqa of the Abu Mustafa canal has chosen to open more valves for a longer time, where they could have also decided to open fewer valves for a shorter time, but with a higher flow. Although some farmers complained because it took more time to irrigate their field, the benefit of a longer turn is that farmers are less affected when pumping has to be discontinued. Pumps can be stopped for anything from 30 minutes to several hours in a day, especially when water levels drop in the canal, or when the electricity is cut (de Bont, 2013).

Pump stations with insufficient water supply or pumping capacity, often experience conflict around the irrigation schedule, which is discussed in more detail in section 4.6. To avoid such problems, farmers may try to augment supply in different ways, as discussed in Chapter 3, in the best cases through replacement or addition of a motor (3.2.3) and in the worst cases leading to fragmentation (3.2.4), abandonment (3.2.1.3) or even removal of the pump station (3.2.1.4).

4.5 Management of hydrants for piped marwas

Similar management problems as discussed above for mesqa valves, are also experienced at the level of (many) marwa hydrants, in stations with on-farm improvement. The farmers tend to open many hydrants at the same time which reduces pressure in the marwa pipe, but spreads the water over all hydrants. Farmers do this when they fear that otherwise they will not be able to irrigate. This approach is more likely to attenuate conflicts between farmers wanting to irrigate than provide all farmers with sufficient water. It is therefore a clear indication of stress. During such periods of insufficient water supply, farmers will look for alternative water sources.

Water distribution at the marwa level is arranged amongst farmers themselves. The example of PS B4 (W10 area) used above suggests that at the marwa level irrigation turns are allocated to hydrants in a sequential order. Although this may be a general principle, field observations suggest otherwise. The hydrants along a marwa pipe are, with a few exceptions, not opened by the operator but by the farmers. The actual irrigation order varies in time and place because of informal agreements amongst farmers to give priority to certain crops or people who switch, share or take over irrigation turns (for example to allow a widow to irrigate at day time). For example (Dutta et al. 2013):

There are some sharing arrangements. A rice farmer gets the share of the cotton farmer for irrigating the rice once every three days, while the cotton farmer gets the priority when the cotton crop needs irrigation. Also, more than one hydrant is often opened at the same time, and the respective farmers share the collective water time. Farmers with immediate irrigation requirements get priority over others.

"Farmers of a marwa have informal organizational arrangements to divide the collective water time. The farmers of a particular marwa are supposed to open the farm outlets for their plots sequentially for a duration proportional to the respective plot area. But they often open more than one outlet at the same time and share the water time…These marwa arrangements are based on the traditional first-come-first-serve system or a priority-based system".

We have found no indications of the existence of proposed marwa-level committees which would arrange water distribution or any other matters at the marwa-level (Gouda, 2009). From the perspective of the water users these are also not needed, since they have long had their own socially acceptable arrangements at the *marwa* level. Or put it differently, these 'committees' already exist and include all concerned farmers, with clearly no need for further formalization.

The station B2 of the Bashair sub-branch canal[6], which has just been installed before the summer season (2014), offers an interesting illustration on how farmers are led to design arrangements by experience. There we observed that 10 hydrants were opened at the same time and that, as a result, the discharge at each hydrant was very low. The operator acknowledged that there was no arrangement between farmers for the opening of the hydrants but asserted that "in case of a problem he would intervene and ask people to close their valves and wait a little bit". Walking around the area we found a farmer and his wife who had been on their field since the day before at 11 o'clock at night when the water first came. They wanted to fill their plot in order to transplant rice; this had happened today because they had already booked some workers from the village for the following day[7]. The farmer said that before, with his individual pump, it would have taken him 2.5 hours to do that, and was clearly unhappy with the problems caused by the fact that he now depended upon the collective PS. Further afield, two hydrants located in rice nurseries did not have their cap. They were fully open and we were told farmers have removed them and gone away, to prevent other farmers from closing them. Although the overall discharge to all plots was maximized, the small discharge available to each of the farmers created problems to all of them. This was the first experiment of this group of farmers with their PS at a peak time. It can be hypothesized that they will be led to designing collective rules in the future.

4.6 Maintenance needs

Maintenance after improvement has particular requirements. The piping of the mesqa has reduced maintenance efforts, in particular the cleaning of an open canal. Nevertheless, *tatweer* has created new problems and maintenance needs, for example the silting up (or blockage) of pipes, the need to clean and desilt the pumping pit and the mesh of the suction pipe, to clean the grid at the inlet of the PS in the canal, leaking valves (that do not close well, see Figure 29), leaking pipe joints, electricity and mechanical problems, etc.

The responsibility for the maintenance of pumps in the PS lies between the operator, and the treasurer or president of the PS. The operator may signal the need for maintenance of the pumps, but since this will incur some costs, the treasurer or president needs to be involved. There are two types of maintenance. Regular (and small) maintenance includes cleaning filters, fixing valves, changing small parts like belts and is much more costly for diesel motors than for electric motors, the former consuming quite a lot of oil. In general this regular maintenance is done based on the seasonal fee that covers energy costs, small repairs, and the operator's wage. For example 150

[6] See IWMI-WMRI report No. 5, '*Water and salt dynamics at the meso-level in IIIMP areas, Mares El Gamal canal*'.

[7] This is a group of 18 persons who take around 2.5 hours for transplants one feddan, for which task he has to pay them 20 pound each. So this is a total cost of 360 EGP/fed.

EGP/fed is collected by 'the treasurer'[8] among farmers. Money is available with the treasurer and if the fee level is too low to pay all expenses, the fee will be increased during the next season.

When maintenance requires larger expenses, such as for the replacement or buying of a new pump motor (e.g. after theft or breakdown), a collective decision needs to be taken (usually after consultation by key people/families in the PS) and the total cost is then apportioned on a per hectare basis to all land owners. When this decision is taken, this special fee is then collected at any point in time.

Figure 28. Example of maintenance needs in IIIMP stations

Cleaning inlet grid | Cleaning suction pipe mesh (pit) | Damaged escape valve

Figure 29. Problems of leakage with alfalfa valves

In particular during the transplanting period with intense and almost uninterrupted pump operation, higher maintenance needs to avoid breakdown and maintain pump capacity can be expected (See section 4.3). To avoid the decline in pump capacity which is estimated at 5% per year, many PS have

[8] As discussed in sections 4.3 and 4.7, the role of the treasurer, i.e. collecting and administering fees, is not always done by the person formally registered as such, but sometimes by the operator, or a respected person associated with the PS.

their pumps maintained about once or twice a year. The frequency of this maintenance varies. A local workshop cleans the filters and replaces small spare parts. Not all PS have arrangements for maintenance as they claim that the pump capacity has not been reduced.

A major maintenance problem lies with the breakdown of the electricity system in IIIMP PS. Although farmers have ways to repair conventional diesel pumps, this is not the case with the electricity grid, as well as with non-conventional diesel motors. A crisis that occurred in station B4 illustrates an extremely negative situation. At the time of rice transplanting, in May 2015, with the highest water demand of the season, the electric switchboard broke down, making it impossible to use the two electric motors. By lack of chance the diesel pump that is to be used in such situations also stopped due to a problem with its shaft. This left the group of farmers divided in three halves: thanks to the small size of the area, one third could irrigate by pumping from the canal with conventional individual pumps, while the second third could irrigate from the drain, leaving a middle tract of 13 feddan without access to water, and recently transplanted paddy fields starting to dry up. In this occasion the helplessness of farmers in front of two technical problems that could not easily be solved locally was glaring.

PS are also affected by what is believed by farmers to be design or implementation mistakes, most commonly in IIIMP areas. There are numerous complaints of:

- pipe diameters that do not fit pump capacity (HP) resulting in over-pressure or over-heating
- pump capacities that are insufficient for the area to be irrigated (with occasional accusations that the motor's specifications do not correspond to what is written on the plaque, or that the motors have been repainted and are not new)
- faulty foot-valves or escape valves

Such farmers' opinions, which could be confirmed, are frequently based on comparisons with other PS in the neighborhood.

4.7 Financial administration

The financial administration of a collective pump station which involves the collection and administration of user fees is formally the responsibility of the treasurer of the WUA. In reality, a variety of task distributions exists in the financial management of the studied PS. In around a 1/3 of the WUAs, a treasurer (*amin sunduq*) is indeed the main responsible for the fee collection in the PS. In slightly less than a 1/3 this responsibility is shared between the treasurer and the operator (the latter might collect the money and pass it on) or done by the operator himself. The treasurer can sometimes also be a trusted figure that is not necessarily registered as the official treasurer of the WUA. A great deal of trust is deposited in this person, since significant sums of money are involved and the ways of administering them are entirely informal. Then there are some cases where the president or another influential and trusted person collects fees or several persons collect the fees. There are also one or two cases where no seasonal fees are collected, since there is no operator active and the PS is operated by the farmers who refill the diesel storage by themselves. Nevertheless, they still need to pay for maintenance, on an ad hoc basis at a minimum.

Water users pay seasonal fees for the operation of the pump in the summer and in the winter. Because the number of operational hours in a PS is normally much higher in the summer, the expenses are also higher in the summer. Nevertheless, the review of the PS shows that the fees on average paid in the summer (78 EGP/feddan; variation: 36-250) are not radically higher than in the winter (72 EGP/feddan; variation: 25-200). In many instances too the fee is the same for both seasons for convenience, with the understanding that the higher 'savings' of the winter period contribute to maintenance or other costs. In most cases this fee covers the salary of the operator (average: 200 EGP/month; variation: 40-400), diesel, oil and electricity, and small maintenance. As mentioned above, ad hoc fees additional fees are collected whenever the need arise.

The IIP project had anticipated that "in order to achieve the desired impact of water use efficiency, IAS through an awareness campaign would train WUGs to collect O&M cost on a *hourly basis of use*" (World Bank, 1994; emphasis added). This fanciful assumption, that seems to pay little heed to the transaction costs that such a practice would incur, reflects the ideological emphasis that the World Bank was placing on pricing and market mechanisms in the 90s. As one would expect, all WUAs without any exception, opted for charging farmers on an area basis; and never even included other considerations, such as the type of crops, or whether a given farmer would also be able/forced to pump drainage water.

The fees are to be ideally collected at the beginning of the season. This happens but when people indicate that they do not have the money at that point, case for which there is a lot of sympathy among fellow farmers, they are allowed to pay during the season when they have the money. At some PS the fees are only paid at the end of the season and some even argue that it is more effective to collect fees after harvest, when famers have money. When farmers continue to default fee payment default rules state that they are not allowed to irrigate. Nevertheless, we have not found many concrete cases in which this has actually happened. Giving water is frequently associated with a religious duty in Islam. Often a solution will be sought in which the person pays later or a family member pays for him/her.

The fee payment also depends on the source of energy used to power the PS. In the case of diesel, it is usually bought collectively in large supply and the fee is either based on the number of hours of use or, most commonly, averaged at the feddan level. A less common option is that farmers bring their own diesel and refill the tank after use, in which case no fee is necessary. The new IIIMP stations have a system of a prepaid electricity card that needs to be recharged when it is empty and the electricity has run out, which may happen any time during the season.

In the case of PS with both diesel and electric pumps, the cost of the two sources of energy are usually conflated and averaged on a per feddan basis. The fact that some farmers may use the pumps more than others, either because they are cultivating water demanding crops like rice or because of some particular soil or topographic conditions, is well accepted and never gives way to a differentiation of fees based on such differences. This is largely based on the understanding that who irrigates a crop with low requirement this year is likely to cultivate rice the following year.

Another particular case is when specific farmers prefer, or are forced, to use their individual pumps in addition to the PS. This occurs for example when they are located at the end of the system and can use the drain. Another example is when farmers in remote parts of the distribution system do not have direct access to the canal or the drain: in times of water shortage, farmers close to the PS use their own individual pumps in order to leave the PS to those remote farmers. The extra costs associated with this parallel or additional individual pumping are always incurred individually in addition of the collective fee, which is never reduced.

4.8 Conflict resolution

Conflict management is considered one of the main irrigation management responsibilities (Uphoff, 1992). But how do water users at the mesqa-level collectively manage conflicts on water distribution? Investigating farmers’ mechanisms for conflict resolution within a PS is not always straightforward, as people sometimes appear to find it shameful to acknowledge that there are conflicts in their community and therefore might deny or underplay it. However, sufficient farmers in Meet Yazid do acknowledge the existence of conflicts amongst themselves. From the sample of PS (49), 14 respondents (almost a third) indicated that after the installation of the collective pump the number of conflicts had increased, 6 that they had decreased, 14 stated that there were no conflicts or it was the same and 15 did not answer this question. This variety again has to do with the local conditions. As we will see below, the majority of conflicts amongst farmers emerge around irrigation scheduling, the severity of which increases with the degree of water scarcity (see section 4.3):

> "A farmer compares a pump station with a relatively good water availability at the Daqalt branch canal with another situation at the tail of a connected sub-branch where the farmers have more problems with water shortage, which generates many conflicts among them."
>
> "During water shortage people go nervous so they reach a peak and fight. After that they become calm again and say they are sorry".

When conflicts emerge, there are different levels at which they can be managed or resolved. Small differences of opinion can usually be locally resolved either amongst the farmers or by the operator who is directly responsible for implementing the scheduling. Conflict resolution within the PS is in a first instance often attempted by the operator: "The operator might first try to resolve conflicts, however when it is complicated he will ask assistance from the five WUA members". The latter indicates that especially when there is water scarcity at a canal, being the operator of a PS can be a very stressful job, as also indicated by the following quote from Mekhezen canal at the tail of Meet Yazid:

> "In the beginning the operator at the pump station was a farmer who received a high wage which was found very expensive by the farmers. So then there was an older man who volunteered to do the job for 40 EGP/month. But he found that it was a very stressful job and he had to deal with many conflicts and fights, because of the problems with renters who were not committed to the irrigation scheduling (agreed among the land owners)."

When the operator is not able to resolve the problems with the farmers he may call in the help and authority of board members, such as the president or the treasurer or other influential (usually large) farmers in the PS. These authoritative figures may have been instrumental in setting up the schedule and its implementation. If the conflicts cannot be solved as such within the PS, it is sometimes necessary to consult with a generally respected or 'wise' man to mediate. Finally, if all previous mediation attempts run aground, the conflict can be treated as a case for the customary form of conflict resolution at the village level. This Arabic customary tradition (*qadat orfia, qadat al arab, maglis orfi*) calls into life an informal committee of several members of respected elderly men to investigate the case and decide on a resolution, which has to be respected by all parties (see de Bont, 2013).

> "Villagers refer to some specific men who are considered wise and kind, for advice and conflict resolution. The villages also have a traditional system of conflict resolution called the *Qadat al Arab*. It is an informal committee comprising the respected men of the village and has five or seven members. The villages also have a mayor, *Omda* and the secretary of the mayor, *Sheikh al Balad,* who play a role in conflict resolution at times" (De Bont, 2013).
>
> "The treasurer of the Bosees BCWUA was once asked at another canal for a problem at a PS. They asked him for the 'maglis el orfi' (customary conflict resolution). They asked him to attend and determine who was wrong. A certain farmer took the right to irrigate out of turn. They had a meeting and the problem was finished" (see IMWI-WMRI report No. 8).

In all of these cases, the involvement of the police only occurs in are extreme and rare cases.

To sanction farmers who break the rules of irrigation scheduling, there is the possibility of giving a fine. This seems to occur only in extreme cases. Some examples:

- They fine 100 LE whoever does not follow the rule and opens his valve not according to the schedule agreed between them.
- If a farmer opens his valve and irrigates not in turn they can fine him and do a report to the police station. This happened before, the police took him to the police station and they can fine him, but you usually let him sign a paper stating that he will not to do that again. This usually works because everyone fears to have that situation.
- At a PS on Abu Mustafa, one man once destroyed the electricity connection and was fined 250 LE; another broke the door of the PS and had to pay 150 LE. The amount is set by three influential men, which act like an "informal WUA", not being officially registered as such (see de Bont, 2013).
- In PS M6 of Mares el Gamal canal (see IWMI-WMRI report No. 5), everyone has signed a paper saying that if he opens out of turn, he will be fined 1000 EGP.

5 Effect of interventions

Section 2 recalls the benefits that were expected from *tatweer* projects at the planning stage and how earlier assessments have evaluated them. Our survey did not attempt to carry out any quantitative measurement of water productivity or equity in supply to evaluate the projects' performance. Although we have asked farmers about their opinions on the changes brought about by the project, we cannot make any balanced assessment based on these statements. One reason is that our sample of interviews is not representative of the diversity of farmers under different pump stations: partly because we have often interviewed pump operators, or farmers located close to the branch canals (which we met when entering the area), who both have an opinion which is *on average* more positive than other farmers' (because they run the pump or because they are at the head). It is a limitation of the survey not to have interviewed a representative sample of farmers for each pump station, which would have required much more time. Such in-depth assessments are being undertaken in the W10, Abu Mustafa and Mares el Gamal areas, and some of the observations made are also mobilized for this report.

But more fundamentally it also appeared that such quantitative assessments, in addition to being very difficult to conduct, would be in most cases irrelevant. If continuous flow were to be established, it would be relevant to check the amount of water abstracted by a given pump station and whether this amount is reduced compared with individual pumping, to assess the expected reductions in abstraction. However, under the present rotational system, with significant uncertainty about timing and supply adequacy, upstream farmers tend to continue abstracting more water when it is available (in order to store it in the soil profile), while downstream farmers will abstract the totality of the water available (supply is less than requirements). However, as discussed below, the question remains as to whether the overall pumping capacity of a group of farmers has been increased or decreased by the introduction of the PS, considering not only the capacity of the new pumps but also that of the additional IPs.

The following subsections therefore limit themselves to providing qualitative hints at how expected benefits may or may not materialize according to local conditions.

5.1 Impacts on land and water productivity

The quantity of water used by a given pump station is unknown and it is impossible for farmers or researchers to really compare actual water abstraction with the total of water which was withdrawn by (all) individual pumps before; at least in situations where supply is satisfactory, usually upstream reaches of the BCs. In downstream and water-short areas, the abstraction capacity of the pump (but actually combined with IPs and conjunctive use from canal/drain) could be compared with the earlier situation by assessing whether the number of farmers that do not meet their requirements have increased or not.

Whether, in upstream locations, the current collective pump withdraws more water than the IPs in the past, very much depends on the capacity of the PS together with the remaining IPs, how many days water is available in front of the station during one rotation. Farmers' answers about that question are quite subjective. It may also well be that the easiness of switching on an electric pump when water is available might result, in water abundant areas, in an increase in water abstraction, compared with individual pumps. Some farmers confused the question about the total pumping capacity with the fact that since they can irrigate their plot much quicker, and therefore thought that more water was available/abstracted.

As explained above, in downstream areas all the water made available is abstracted and made use of, implying a high use efficiency because they have to make use of any single drop reaching their area. In this case, it is however irrelevant to look at efficiency because supply is generally well under requirements. Deficit irrigation is of course very 'efficient' (the highest water productivity is sought), but it's not the intention to achieve a high efficiency by making farmers water short.

In other words, the behavior of the upstream farmers is unlikely to have been changed by technology (because it is primarily dependent on their perception of the predictability of supply), nor did that of downstream farmers. The total quantity of water abstracted along the branch canal has also not changed and is still shaped by the rotation system in place. Of course the seasonal quantity may change depending on the location of water at the macro level, but this has nothing to do with *tatweer*. The spatial distribution of water within the BC command area, however, may have changed (see below).

Whether yields have increased or not is also very difficult to assess. Yield integrates a large number of factors and causalities which are hard to establish or isolate in terms of their impact. Yields may slightly increased, for example, as a result of more water being available in the canal in a particular year, but this has nothing to do with *tatweer* itself. On the contrary, it was reported that yields in the terminal parts of MYC had decreased because supply had been short and the corresponding increase in the use of bad quality drainage water had impacted yields. Elsewhere, one farmer mentioned that yields were improving but that this was a result of constantly improving the land from quite saline initial conditions. Another farmer stated that it was due to installing subsurface drainage. In most cases farmers reported no change in yields.

A few clearer cases were linked to the recognition that crops located far from the canals were now better served by the piped system and as a result were also getting better yields. Beyond the difficulty to estimate quantitative changes and causalities the assumption at the time of the project appraisal that "crop yields would increase by 8 to 15 percent for winter crops and by 28 to 41 percent for summer crops" (World Bank, 1994), appears rather heroic.

5.2 Impacts on equity

There was more consensus on the positive impact of improvement on distributional equity among the farmers sharing one pump station. Indeed, since most water user groups designed rules that are very equitable in terms of time allowed per feddan, there is a recognition that farmers formerly located at the end of the mesqa and/or far from the branch canal are now better served. This varies depending on topography, the size and shape of the command area, the nature of the earlier mesqa (slope, depth, width), the variations in pressure in the distribution network, etc. As some farmers reported:

> "After the pump station the farmer at the tail end of mesqa has the same amount of water as the one at the head". Or: "At the beginning the mesqa was opened and every one can put his own pump for no specific hours, sometimes for 3 hours; the water could not reach the lands at the tail end; now it is organized by specific time for each feddan to distribute the water to all the served area equally".

This formal equity, however, is altered by parallel or conjunctive use of IPs (see section 3.2.5). Farmers with fields located along the branch canal who can still use their individual pumps, in addition to, or in replacement of the PS, are clearly at an advantage. Others observe that "people at the tail can get drainage water when they do not have enough. The inequality lies in the use of canal and drainage water".

But inequality also results from the distribution network itself. Although equity in times of water shortage is established through rules that in most cases grant each feddan a fixed amount of time, with some variation depending on the crop, the discharge at the outlet of each valve varies depending on topography and on the design of the pipe network. We observed several cases, in particular in networks including marwa pipes, where design mistakes made it impossible to, for example, use three pumps together because of the overpressure created in a too narrow pipe. In one of the PS, the diameter of the pipe is reduced from 40 cm to 30 cm in the last reach of the mesqa, and this causes the water to overflow the tower when 3 pumps are operated together. In other systems, low pressure, and therefore low discharges, are observed at some points in the network. In one of them, the operator explained that it was compensating for this lack of pressure by slightly closing the upstream valve when it was operated together with a downstream valve, in order to increase discharge at the latter. Such technical problems may also be due to late changes in the pump's capacity, the number of valves, or other technical parameter, as a result of farmers' pressure.

Another important equity issue is whether *tatweer* increased the equity of distribution between PS (or former mesqas) along the BC, as compared to a situation with only individual pumps. In other words, whether the *spatial pattern* of water abstraction within the branch canal command area has changed. This chiefly depends on how the total abstraction capacity (PS + IPs) of a group of farmers has changed as a result of the introduction of *tatweer*. In IIP areas design criteria were quite generous and the PS provided 2 l/s/fed (continuous) as an order of magnitude; to which must be added the individual pumps if and where they have remained. It is quite likely that many or most farmers have benefited from an increase in abstraction capacity in such conditions. With little change in the management of and the allocation of water to BCs, downstream areas may have been impacted negatively.

In areas where individual pumps have remained, which is almost everywhere but to different degrees, the question of competition between individual and collective pumps arose several times. Along the tail reach of Meet Yazid canal (Ganabiya East Sidi Salem), one farmer complained that the numerous IPs were abstracting a lot of water and impacting IIP stations negatively, reducing the availability of water compared with the earlier situation. A similar opinion was voiced in Al Zarafa canal, where farmers felt it was unfair that farmers who had refused *tatweer* could abstract water before them and felt that this was reducing their supply. But the opposite opinion was also heard in the Masharqa canal, were a farmer believed that the amount of water had been 'reduced after IIP because the capacity of PS upstream became high and they took more water than before'. These reactions are of course rather impressionistic because it is impossible for someone to know whether a perceived reduction in supply is due to what people are doing upstream or to the overall supply.

In a context where the rotational system of distribution is maintained, the name of the game remains ensuring the highest pumping capacity possible. This involves collective (adding one pump, changing a motor, intervening in different ways at the time of design to obtain from a bigger pump capacity from the engineer…) and individual strategies (using individual pumps to abstract water from different sources). To our knowledge there is no study of how farmers' pumping capacity has changed as a result of the implementation of the project. In any case, such a comparison of the pumping capacity *ex ante* (IPs, some *sakias*, *tanburas*) and *ex post* (PS, IPs, sakias/tanburas) would be fraught with difficulties. The limited flow available in the mesqas in general do not allow all IPs to work at the same time (with the usual accepted pattern of upstream IPs pumping water first).

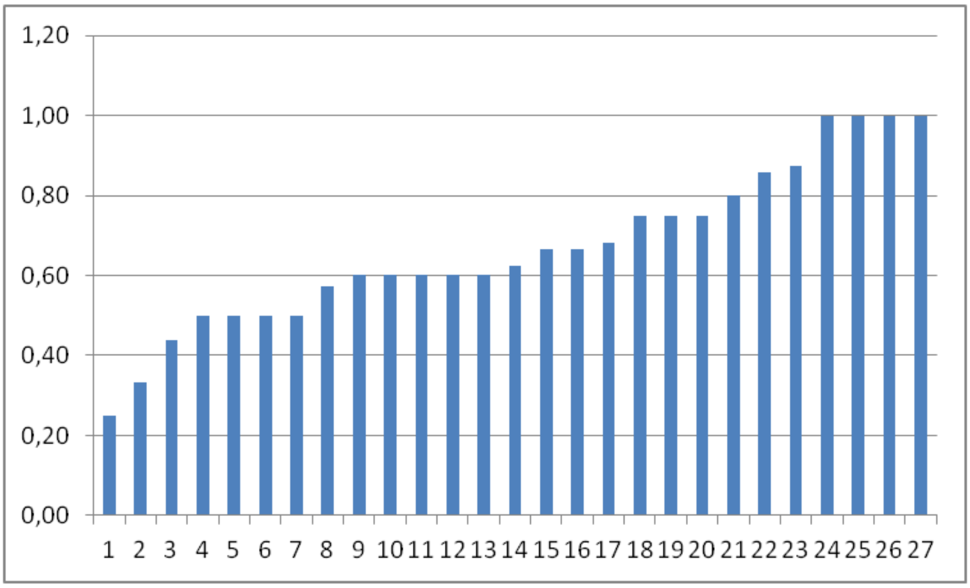
5.3 Impacts on labor requirements

The overwhelming majority of farmers reported that the time taken to irrigate their plot had significantly decreased. The reason is that after on-farm improvement the discharge provided by a mesqa valve to one marwa, or by a marwa hydrant to one field, is in general higher than the discharge that was provided by the individual pumps in the past.

The coefficient of reduction of the time spent for irrigating one feddan as indicated by farmers was on average 0.67. Figure 30 shows the distribution of this coefficient for 27 farmers (others have reported a reduction without estimating it). Only one farmer claimed that irrigation time had increased, but did not quantify this increase.

To this reduction in the time spent for irrigation must be added the time saved by removing the burden to bring the IP and the hose to the field (generally on a cart drawn by a donkey). Most of the IPs, however, are fixed and there is no clear assessment of how much time that saves for each irrigation.

Figure 30. Reduction of the pumping time per feddan, after *tatweer*



Not included in this sample is a farmer who explained that it could take 17 hrs for him to irrigate one feddan of sugar beet at the time of land preparation, because the land was not even and the marwa used to leak a lot to the drain.

This reduction in labor time has to be weighed against the increase in the time devoted to collective action (coordinating the timing and length of irrigation, maintenance, fee payment, conflict resolution, etc.) and the problems associated with the dependence on a common pump station and network. Those transaction costs are largely concentrated in a period of 2 to 3 summer months each year, and are limited in case there are no conflicts. Nevertheless, farmers sometimes regret the loss of flexibility in determining when to irrigate. Practically it is impossible to establish a balance of such changes.

In addition, whether there is an opportunity cost associated with a hypothetic overall reduction in labor time is doubtful. In one instance only, did one farmer using an individual pump mention that if he did not have to sit and wait for water on the side of the canal to switch on his pump, he would have more time to do other things (but the problem was the intermittent flow).

5.4 Reduction in the use of drainage water

The reliance on a single lifting point was supposed to do away with the need to tap water from the drains, and therefore to avoid bringing water of poor quality and loaded with salts.

Whether the overall use of drainage water has decreased or not is obviously not easy to assess, except in the cases where such use existed and disappeared, or vice versa. It can be hypothesized that farmers with plots located close to the canal will not have a clear idea of these changes.

41% of the farmers interviewed reported that the use of drainage water had increased after *tatweer*, especially in canals such as Shalma, El Monshah or Mekhezen, where in two locations farmers came to use drainage water when they did not before. Of course these changes can also reflect local changes in the overall availability of water and, therefore, cannot be fully ascribed to the establishment of *tatweer*. 19% stated that the use of drainage water had decreased, 19% that it had remained the same, and 21% that they had no access to the drains (or did not use them).

These results are rather inconclusive and hard to interpret. The most important point to be recalled here is that the overall supply management of the system has not been changed and, therefore, except for some relatively minor differences between the years[9], the amount of water received by a given branch canal has not been altered significantly. In some places *tatweer* may have increased the overall abstraction capacity of upstream farmers (including IPs); and as a result downstream areas have been further affected and have continued resorting to reuse of drainage water.

In any case, as can be seen from Figure 31. Occurrence of pumping from the drainage system (survey of IPs, W10 excluded), which shows the location of around 2000 IPs that have been registered along main and secondary drains of Meet Yazid command area (but also from the figure in Box 1, in section 3.2.5), the reuse of drainage water is still ubiquitous (the Wasat (IIP) area, is delineated in red). It is safe to assume that there has been little change in the quantity of water reused from the drains, and if this has been the case it is more likely to be the result of a change in supply; or in demand, associated with the growth of the rice area.

5.5 Financial considerations

There are three categories of costs for the farmers: 1) the annual fee that they must pay to the government, as a contribution to the overall investment of the IIP program; 2) the cost of replacing broken or stolen motors, or of shifting to electric pumps; 3) the running costs (electricity/diesel + maintenance + operation).

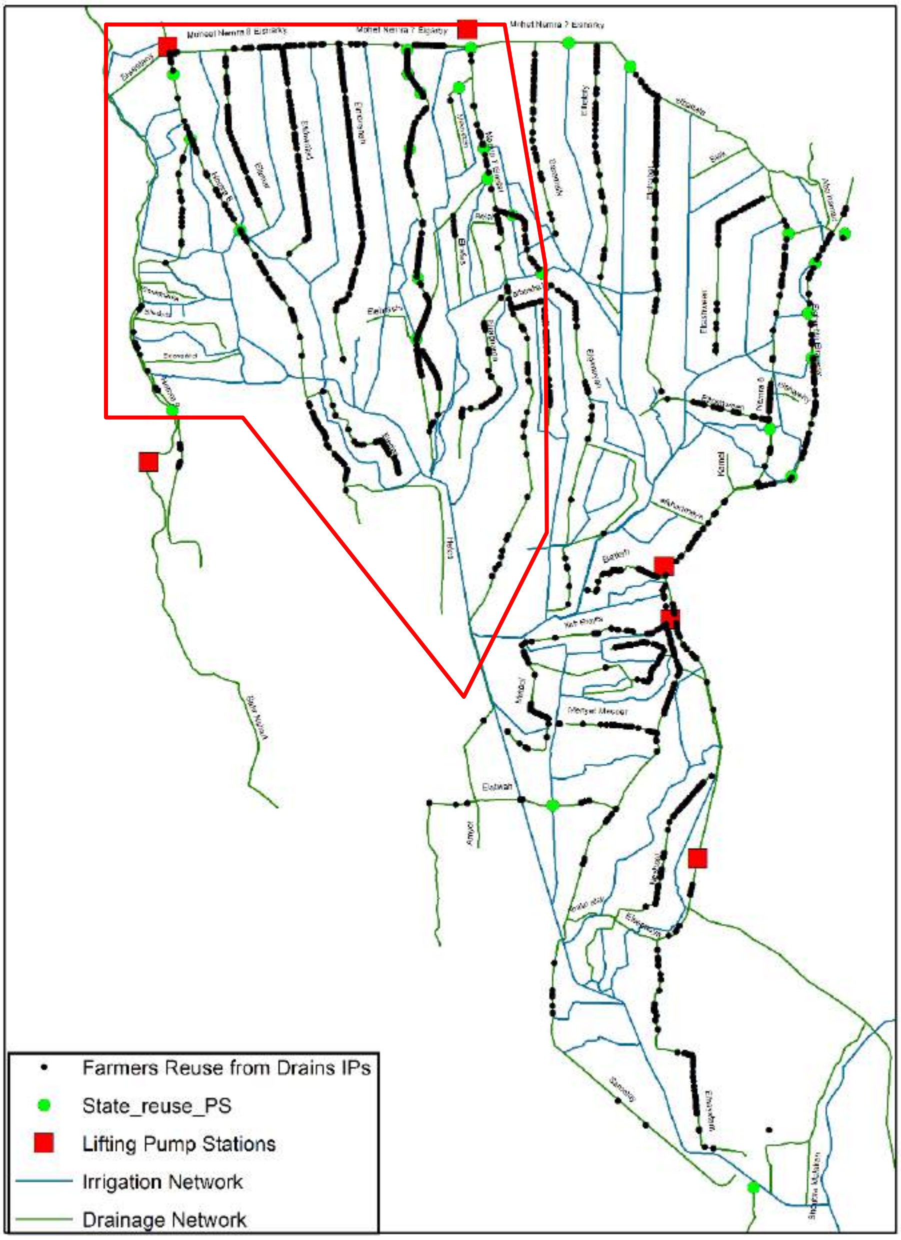
5.5.1.1 Investment costs

As mentioned earlier most farmers are very confused about when and how much they will have to pay, in the case they have not yet started to pay. Those who have started to pay have a clearer idea, although several times farmers would disagree about costs and other details of the payment. This confusion was illustrated by one farmer who said that they were initially told, at the time the project was presented to them, that they should contribute an amount of 3000 EGP/feddan, but that when

[9] See IWMI/WMRI Report No 1, that shows some results on the delivery to branch canals in Meet Yazid area, as collected by IIP/IIIMP monitoring and evaluation programs.

he went to check at the main office in Tanta he was told that the cost to be recovered would be 7000 EGP/fed.

Figure 31. Occurrence of pumping from the drainage system (survey of IPs, W10 excluded)



It was not immediately clear why farmers were not given clear-cut information on the cost of the project. When asked what was the cost of the diesel pump that was being added to his IIIMP pump station one farmer started to say 12,000 EGP, but the contractor that was present at the scene intervened to say "we don't know the cost". Checking later with the contractor he explained that they did not try to hide the cost but rather did not want to announce one cost and later have project engineers coming with another value, because this would only create conflicts.

There were discrepancies regarding the number of years between the reception of the project and the first year of payment. In one station farmers mentioned that they had not paid for the last 10 years and were not sure why (since all others in the same branch canal had already been paying for seven years). Others, however, already started paying after a few years.

Several water users were aware that payment was higher during the first three years, when farmers had to reimburse the pump, and then lower during 20 years, to pay for the pipes. Several farmers did ask whether the project was a loan or a grant, mentioning they were told that it was a gift from the EU, the German, the American, or the Japanese government, depending on the case. In one area, where farmers were told the project was a Japanese gift, it was reported that they were asked to pay 550 EGP/y, 2 years after the construction only. While some farmers started to pay, a group formed and went to court to explain their grievance. The judge ordered to stop the payments until it would be clear whether it was a gift or not.

In W10, in spite of the original promise that the improved marwa would be delivered for free, one farmer explained that it is actually being charged to the farmers.

Figure 32 shows the variability of the first payment indicated by farmers; the value of the long-term payment varied between 50 and 200 EGP/feddan. There are considerable differences between these values and it is not clear how much this is due to:

- effective differences in per feddan costs (reflecting differences in the size and the shape of the command area, and special requests made by farmers),
- differences in construction dates (the unit cost of one station has varied along the lifetime of the IIP/IIIMP project, as well as the relative value of the Egyptian pound),
- farmers not being clear about this cost (e.g. some of the respondents may have been tenants who may not have direct information on this).

Few had a clear idea of the overall contribution they would have to make, but the amounts mentioned ranged from 2000 to 7000 EGP/feddan, which somehow matches reality. Actual costs charged to farmers for IIIMP stations, as indicated by one of the contractors, varies between 3000 and 5000 EGP/fed, the values near the lower bracket corresponding to larger areas that allow for some economies of scale.

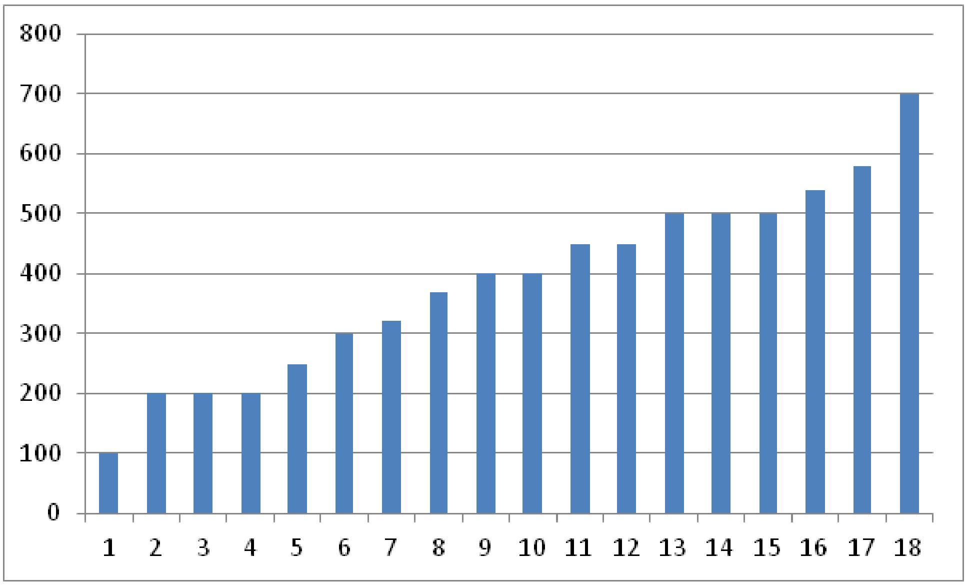
But this unit price can also be raised under particular conditions. One special case is when the station is not constructed at the head of the former mesqa but at some distance inland, being connected to the branch canal through a large diameter concrete pipe (see Figure 4D). This can be related to particular circumstances, such as the owner of the land along the canal refusing to cede part of his land for the construction of the pump station, the will not to have the station located near a mosque (where the noise of the motors could disturb prayer), or to a long mesqa necessitating the construction of more than one station.

The neatest example of this latter situation can be observed in the IIIMP pump station recently built in the downstream reach of the Halafi canal. Long (800 m) and large mesqas serving several hundreds of feddan have been replaced by a concrete pipe that came at a cost of 4000 EGP/fed, added to the 6000 EGP/fed of the pump station itself. This cost includes the house itself, 2 electric pumps and one diesel motor, all protected and placed within the house. The cost of the pump house (3m x 3m) for two electric pumps is 25000 EGP, while for a bigger house (4m x 6m) that can accommodate the diesel pump, the price is 48000 EGP. For the 50 feddan served by the pump the cost of the additional diesel pump (25000 EGP/50 f) and of the enlargement of the station (23000 EGP/50 f) is around 1000 EGP/fed, which is well accepted by farmers.

Several farmers did ask whether the project was a loan or a grant, mentioning they were told that it was a gift from the EU, the German, the American, or the Japanese government, depending on the case. In one area, where farmers were told the project was a Japanese gift, it was reported that they were asked to pay 550 EGP/y, 2 years after the construction only. While some farmers started to pay, a group formed and went to court to explain their grievance. The judge ordered to stop the payments until it would be clear whether it was a gift or not.

In W10, in spite of the original promise that the improved marwa would be delivered for free, one farmer explained that it is actually being charged to the farmers.

Figure 32. Distribution of the values of the initial payment by farmers (for the investment in pumps)



All the farmers concerned by *tatweer* and requested to pay are reported to be paying their share, if and when the pump station has been received officially. They state that they cannot refuse to pay the tax collector (their payment is pooled with other taxes, like the land tax, or the reimbursement for the subsurface drainage) because they would be jailed for that, and there were only a couple of fuzzy cases about refusals to pay (Some farmers mentioning that since the 25 January revolution they refused to pay for IIP). However, project completion documents from IIP (World Bank, 2007) refer to a percentage of financial recovery of 38% and it is apparent that farmers are not willing to report any such defaulting in interviews.

There were cases of conflicts between farmers and *tatweer* officials, when the tax collector received a list of beneficiaries that were asked to pay for the investments but who refused to pay, claiming that the pump station did not work and had not been officially 'received'. At the Gad Alla canal and in other cases, this disagreement gave way to court cases which are still running (see section 3.2.1.1).

With regards to the marwa improvement projects, it was also striking to observe that most farmers (who had not started to pay because the IIIMP project is very recent) stated that they had no idea of how much they would have to pay. One said they were used to such government projects and did not need to ask how much they would pay.

A few anomalies were found, whereby farmers had not started to pay even after 10 years of use. This was observed, for example, in Abu Mustafa canal and in Saf-Saf canal, and the reasons for this remained unclear.

5.5.1.2 Replacement costs

Although replacement costs are usually understood as the replacement of the equipment at the end of its life duration, it is apparent that early replacements are also motivated by the theft of the pumps, or the will/necessity to shift to electric or more powerful pumps.

The cost of changing from diesel to electricity pumps differ from place to place according to several factors such as the proximity to existing electricity lines, the number and capacity of the motors, whether these are new or second hand, etc. In 2010, some farmers at the Daqalt canal partly switched from diesel to electricity. They changed one diesel pump to electricity at the cost of 15000 EGP, but left the other diesel one in case there is an electricity cut. This was strategy that was followed in many PS and should be understood in the context of the many electricity cuts and diesel shortages in the countryside, in particular after the Revolution of 2011.

The cost of an electric motor is typically 3000-9000 EGP depending on power and quality, but used ones can be found for 2000 EGP.[10] The electricity company collect a so-called 'insurance cost' of about 300-700 EGP/HP of power installed, which presumably reflects the cost of increasing the load capacity of the power line. Sometimes farmers register for higher pump capacities to enable them to add more pumps in the future, if they need. Moreover, the costs of the electric connections, wiring, transformer, etc. vary a lot according to the location of the pump with regard to the main electric source (the villages). Often a transformer is needed and the cost varies according to the number and capacity of pumps which are connected to it. In the El-Khawaled canal, the farmers of 6 pump stations arranged together and contacted the electricity company to have one transformer, and the total cost they paid to bring electricity to the 6 pump stations was 180,000 EGP. The transformer is generally sufficient for at least three stations and it is generally not cost-effective to request connection of one single station, unless this can be done without addition of a transformer.

Additional costs include the purchase of diesel pumps that are added to the pump station, in order to deal with electricity cuts. The cost typically ranges from 7000 EGP to 25000 EGP, the latter value corresponding to the pumps proposed by and purchased through IIIMP, which are fitted to the pump station itself. Some pumps are more sophisticated and more expensive: for example one group bought two new pumps of 7.5 HP, one water-cooled (7000 EGP) and the other air-cooled (13000 EGP).

5.5.1.3 Running costs

To run the pump stations the farmers collect the operating costs which vary according to the season (winter/summer), the actual cropping pattern, the type of power they use (diesel /electricity), if they hire an operator or not, whether they include a provision for maintenance, and of course the average number of hours that farmers are able to operate the pump according to the availability of water. The number of farmers sharing the pump is affecting the value they collect when they also share the (fixed) cost of maintenance. Although minor running maintenance costs are generally included in the seasonal fee, the more costly interventions, in case of major technical problem, are dealt with by collecting ad hoc sums from farmers, in all cases on a per feddan basis.

[10] Individual pumps of 5 to 10 HP cost between 4 and 12,000 EGP when new, 2000 to 6000 EGP when used.

The salary of the operator varies from 40 to 300 EGP/month and there are cases where he volunteers to operate the pump without any salary. In most of such cases the operator usually has a large land irrigated from the pump station, and/or has no other job, lives nearby, or is a member of one single large family using the pump. There are also cases where there is no operator (see above).

In the case where farmers are only using diesel pumps, they normally replenish the tank after using the pump and the seasonal fee does not include those expenditures. When the pumps are electric a seasonal fee is generally collected. In more recent IIIMP pumps electricity is often paid through a prepaid card (with a value of 500 EGP or more) that is replenished when need be and fees are collected accordingly, that is, not necessarily according to the season.

With so many variations it is therefore very hard to compare O&M costs on the sole basis of what is collected seasonally. A typical value for seasonal water pumping costs is between 70 and 100 EGP/fed and the reduction in costs compared with individual pumps is consistent with the values considered in the project feasibility report, that is, between 35 and 42% (World Bank, 2007).

Shifting from diesel to electric pumps normally comes together with a reduction in running costs (between 20 and 40% per season, as an order of magnitude), but of course the benefits is less clear when the investment cost is factored in, and also when one takes into consideration the sometimes considerable parallel pumping still carried out with IPs.

5.6 Increase in the land area cultivated

Another expected benefit from *tatweer* was that the area occupied by the open mesqa would be cultivated after having been filled in. The same expectation applied to pump stations with on-farm improvement, in which opened marwa would be replaced by buried pipes.

We have not conducted a systematic assessment of how much land had been gained for cultivation. The overall impression is that in most cases the mesqa, once covered, has been left uncultivated and frequently used as a public space for an enlarged road, animals, drying crops, etc. The main reason for that is the private ownership of the land occupied by the earlier mesqa, with adjacent land having boundaries that correspond with the center of the mesqa, although owners have to concede a right of use to downstream farmers (Irrigation and Drainage Law 12/1984). A quite typical situation was observed at the beginning of the Bashair branch canal where the farmer whose land is located just after the pump station was claiming the stripe that had been filled in. In a heated discussion, the operator and the WUA president, were explaining him that other farmers were afraid that he would build a house on this land and therefore preclude the reopening of the mesqa, should the need arise. The 'easiest' solution to avoid conflict, in such a situation, is therefore *not* to use the land and let it uncultivated.

In most cases a road was already existing along the mesqa and the road was kept and sometimes enlarged. If there is no road then the additional plot is likely to be claimed by both adjacent farmers, which also may lead to a gridlock. This problem is solved in the case in which the same farmer owns both sides of the canal.

The same applies to marwas, with the additional factor that in several cases farmers prefer to keep their marwa opened. This is a response to worries that a problem might occur with the buried pipes, or with the pump station altogether, meaning that it is safer to keep the network of marwa to convey water from the branch canal to one's field in any circumstances. There was also an instance in which marwas were quite deep in order to also serve as field drains, and farmers wanted to maintain them.

A very peculiar situation could be observed in the downstream part of the Halafi canal, where two long/large mesqas have recently been piped and equipped with IIIMP stations. As can be seen in Figure 33, the width of the filled-in mesqa with two roads on each side is very large. In one case a 3m-wide stripe of land (between the line of electric poles and the road) has been added to agricultural land on both sides, while in the other case this has not been done. In both cases the remaining empty stripe is very large. When asked why they don't keep only one road, farmers said that it would not be accepted because it would only favor one side and would be inequitable.

Figure 33. Making use of the area originally occupied by mesqa and marwas

Filled-in mesqas, with no additional cultivation (1)		Filled-in mesqas, with no additional cultivation (2)	
Filled-in marwa, with no additional cultivation (the marwa is not well compacted, has been reopened for repairs and is not cultivated		Filled-in marwa, incorporated to the field and with additional cultivation	
New piped mesqas in Halafi canal. No land is gained and a very large road is created		New piped mesqas in Halafi canal. Some limited gain in land, and 2 roads maintained	
Old marwa system in Halafi canal. 4 parallel marwas retained		Old marwa system in Halafi canal. 7 parallel marwas retained	

The same seems to be happening with the marwas, which run in parallel and therefore take a lot of land. The figure shows pump sumps serving respectively four and seven marwas. Farmers reported that they would keep them because otherwise the benefits would only accrue to those located along the marwa. Although the establishment of the IIIMP stations is very recent in this area (and it is therefore possible that changes will still occur in the future), the equity argument and the intention to avoid conflicts seems to prevail and work against the transformation of bare common land into cultivated land.

5.7 With/without marwa improvement

The Strategy of Sustainable Agricultural Development 2030, issued by the Ministry of Agriculture and Land Reclamation (MALR) around 2009, aims at developing, among other things, "a national irrigation modernization program that gradually improves the efficiency of water conveyance and distribution systems, as well as the efficiency of on-farm irrigation systems. The national program would aim to modernize irrigation in an area of 5 million feddans and increase farm-level efficiencies from 50 percent at present to 80 percent by 2030" (World Bank, 2010).

In parallel with the IIP/IIIMP projects, the MALR has taken up the idea of extending piped distribution networks down to field-level hydrants, tested in the W10 area under the last phase of the IIP1 project, as an add-on to the IIP. This idea has been considered positively and funded by the World Bank/AFD (2010) and IFAD (2009), under the FIMP (Farm-level Irrigation Modernization Project) and the OFIDO (On-Farm Irrigation Development Project in the Old Lands) projects respectively. The FIMP project intends to focus on the upgrading of IIP stations over an area of 200,000 feddan by providing electric lines and motors to 75% of them, adjusting IIP hardware when needed, and adding marwa pipes and hydrants. Activities have started in the Mahmudia canal command area but not in Kafr el Sheikh. OFIDO, in turn, focuses on proposing a package of on-farm pipes and hydrants to recently implemented IIIMP pump stations. Several of the PS visited (in W10 and some IIIMP areas) had been provided with on-farm infrastructure, as part of the OFIDO project. Six out of the twelve IIIMP stations monitored as part of our 'meso-level' study (see IWMI-WMRI report No. 5) were also equipped with such marwa pipes and provided an opportunity for further observations, although we did not attempt a full assessment of on-farm improvement projects. Since the technology and the objectives of the two projects are by and large equivalent, we also comment on the FIMP's working hypotheses, in light of the observations made.

5.7.1 Expected and realized benefits

The World Bank's (2010) FIMP project is predicated upon the following expected benefits to the farmer:

> (i) production and productivity increases (due to enhanced water distribution efficiencies, timely irrigation, equity for tail end farms, improved water quality and quantity, improved drainage, reduced water table and water and soil salinity, etc.); (ii) land gains for production and/or communal service space (due to covering of marwas); (iii) reduced irrigation costs (depreciation and O&M costs of pumps: energy costs, labor, etc. due to enhanced water productivity, fertilizer savings, reduction of weed control costs and of marwa maintenance costs); (iv) change in cropping pattern (due to improved reliability and timely access to water, less risks, and renewed technical assistance providing support for reconversion to higher value crops); and (v) increased water productivity (conveyance speed is increased, controlled drainage is introduced, land leveling is applied, higher yields and lower costs of irrigation are attained, etc.).

As indicated earlier the clearest gains of the on-farm improvements, and the closest to project assumptions (-30%), extend those already effectuated by the mesqa-level improvements, namely the savings in labor and energy costs. These benefits, however, vary a lot depending on the geometry of the area and the length of the earthen marwas.

FIMP also expects increases in yield of 4-20% for various crops, according to "conservative estimates". Given that the overall quantity of water delivered is basically unchanged, increases in yields are expected to result from a more equitable distribution of water at the mesqa level. This benefit (enhanced equity) has already been achieved at the mesqa (valve) level and should not also be ascribed again to the on-farm level. In any case it is very dubious that a yield gap of up to 20% pre-existed since 1) farmers use drainage water to make up for the possible lack of irrigation water, 2) deficits are primarily attributable to insufficient water supply at the level of the branch canal (in particular the middle or downstream reach of branch canals). Likewise, it is assumed that "the greater security of water delivery and more equitable water distribution coupled with demonstrations of horticultural crop production would also encourage production of high-value crops such as fruits and vegetables". It was clear from our survey that irrigation improvements failed to deliver a "greater security of water delivery" because this security is primarily based on the overall amount of water distributed and on the proper execution of rotations between and within branch canals. This has little to do with both mesqa and marwa improvements. The objective of producing high-value crops is a standard one in irrigation projects: under the prevailing conditions of access to irrigation water, land fragmentation and the (seemingly forgotten) marketing risks and constraints of these high-value (but also high-input) crops, such an objective is unlikely to be fulfilled.

The project investments are expected to allow "about 15-18 percent of water savings", a percentage that looks out of sync with the order of magnitude of seepage losses at the marwa level. Further, it is not clear whether these numbers also include savings associated with improving land leveling, an activity also included in the project. A risk anticipated in the project document is that while "farmers are expected to lead to reduced irrigation water applications, [they may] possibly not reduce crop consumptive use (or evapotranspiration)". Indeed, if yields are to increase it is a safe conclusion that evapotranspiration is going to *increase* as a result. This risk is vaguely dealt away with by wishing that "farmers [will] switch to alternative cropping patterns with less water-consuming crops."

An intriguing emphasis is placed on the role of Marwa Committees which, together with "irrigation technology modernization and the strengthening of local farmer organizations" will further improve overall water and land management at the local level. The reasons for vesting such high hopes in these marwa committees, which are mentioned in passing in the 1984 law, to be formed in no less than 20,000 marwas, are not entirely clear. The idea of marwa committees conforms to a type of development intervention inspired by a normative ideal of bureaucratically organized development that place unreasonable expectations on the role and the sustainability of formal water user associations. It is apparently uninformed by the real-life workings of WUAs at mesqa level (see section 4) and BCWUAs at the branch canal level (see IWMI-WMRI report 8).

IFAD's (2009) OFIDO project list similar benefits but does not make explicit the assumptions made about expected changes, limiting itself to citing research by WMRI in W10 that on-farm improvement increases field water use efficiency of rice and cotton under piped irrigation systems of 35% and 28%, respectively.

5.7.2 Observations on implementation and problems faced

The issue of collective management of marwa pipes and hydrants has been dealt with in Section 4. When a rotation is applied to the valves, generally during two months of peak demand in summer, then the time is sub-divided at the farm or plot level. This is just as was the case before, except that there is no need to wait for the marwa to fill to convey water to the next plot. As a result, marwa-level improvements do not further improve equity in distribution. Out of rotation periods, or if and when farmers are unable to set up a rotation, as observed in some of the new PS of Mares el Gamal canal, individual hydrants may have a negative impact because in the absence of collective rules it is difficult to control multiple and dispersed outlets managed by farmers (unlike a limited number of valves managed by the pump operator).

Regarding the introduction and design of the marwa improvements in IIIMP areas, we found that farmers were proposed this additional option a few weeks or months after having received their PS. In contrast with mesqa-level improvements, this seems to have happened on a purely on-demand basis. Likewise, a great deal of flexibility in design has been maintained. For example, at some stations only a part of the marwas had been piped, whilst the remaining marwas were left open, according to farmers' choice. Interestingly, in some IIIMP cases farmers have pleaded with the engineers when constructing the pump station, to keep the marwa canals open in addition to the pressurized pipe system. In this manner, they can irrigate with IPs when the electricity is cut. In another case, farmers also wanted to keep the marwa, because it was also serving as a field drain.

Another interesting adaptation of the marwa improvement is that some farmers, notably in W10, have connected their individual pumps with the end of the marwa pipelines, or in one observed case, at the end of the mesqa pipe itself, so that they can abstract water from the drain and inject it into the network. This makes parallel and conjunctive use of PS and IPs possible and changes the supply-demand ratio (see section 3.2.6).

But the main problems experienced with the OFIDO marwa improvement in Kafr el Sheikh were related to the poor quality of the materials used, due to insufficient standards, related to cost reduction measures. Interestingly, may be informed by the experience with IIP, the FIMP's document identifies the "poor quality of materials and workmanship, particularly of buried pipelines but also of other project works, [as] a major project risk, dispersed as they are and largely hidden from view". The mitigation measure proposed: "FIMP is instituting a system of works quality inspection and control whereby all inspection and acceptance is by agencies different from that which executed the works", is yet to be tested. Faced with widespread problems of quality of material and workmanship, IFAD was reported to have upgraded the technical specifications of the material to be used (PVC thickness, etc.).

In the case of the OFIDO projects visited, farmers faced with leaking buried pipes or hydrants were extremely angry to find themselves unable to easily tackle the leak and prevent damage to crops by water-logging. In some cases a (belated) intervention by the contractor could be obtained after much mobilization by farmers (since a one-year guarantee apparently applies). In the case of such failures it is likely that farmers will de-link the marwa pipe from the valve and revert to using marwas.

Figure 34. Seepage from buried marwa and mesqa pipes creating water logging

6 Unpacking causalities and acceptability of the project

6.1 Analysis of trajectories

We have found a large sample of situations, ranging from ones where the pump stations are used to the satisfaction of farmers since the beginning, to others where they have created conflicts or been abandoned altogether. This implies that it is crucial to understand the particular contexts or conditions in which IIP interventions are likely to be more successful than in others, which will be detailed in the next section.

We look here at the high diversity of what we have called *trajectories* followed by the IIP pumps, meaning that they have been subjected to many adaptations, in both their hardware and software dimensions. The most striking observation is that *few* pump stations are working with the initial pumps, engines, design areas, and target farmers that were present at the time of implementation. This is not necessarily a problem, as it shows in part that farmers are innovative and able to 'reshape' a given technological innovation so that it fits local conditions.

Figure 35 recaps the different evolutions analyzed in the preceding section. It is important to note that the strategies associated with these different trajectories are *not* exclusive and can sometimes be simultaneously combined (e.g. a more powerful electric pump is bought in replacement of a diesel pump to both reduce energy costs and increase pumping capacity), or happen sequentially. Trajectories fall under four categories (leaving aside cases where the pump station is not being used anymore):

- The first category includes efforts to *increase supply availability* at the pump level: this mostly refers to efforts by downstream users to *maximize the flow available* in front of their pump station by complaining to gate-keepers/engineers, and sometime higher-level politicians or decision-makers, so that the rotation be enforced and/or the number of days 'on' increased[11]; lowering the intake of the pump (the pipe between the canal and the pumping pit) so that water can be withdrawn even when the water level is at the lowest; tampering with hydraulic structures (for example damaging a gate so that it cannot be fully closed); and building obstacles and weirs with stones, mud or trash in the canal in order to divert water to their inlet.
- The second strategy is geared towards *increasing the abstraction capacity*: this can be done through buying a more powerful engine for the pump; adding another pump (in general a third one added to the two existing ones); using both electric and diesel pumps, so that water can still be abstracted in case of power cuts or diesel shortages; and adding IPs along the branch canal for direct irrigation.
- The third category refers *to increasing supply* by tapping other sources (conjunctive use), which in the case of Meet Yazid means using drainage water (from main, secondary, and tertiary drains) through IPs that in general feed into local marwas but can also be connected to the piped network. In the delta, many farmers have also dug wells, but this solution is rarely observed in the Meet Yazid command area because groundwater is saline North of Kafr el Sheikh.[12]
- The last category entails that farmers can respond by *improving internal management* rules: this does not increase the overall availability of water but can help in ensuring equity and

[11] For example farmers along Ghabat canal long complained that they needed one additional day for their canal and this was granted to them by the new district engineer.

[12] See IWMI-WMRI report No. 6 'Survey of groundwater use in the central part of the Nile Delta'.

reducing conflict. This means avoiding situations where a few farmers would have too much water to the detriment of others, and therefore improving the matching of requirements at the individual level.

Many of the pump stations that are working are able to do so only because they have taken steps to rebalance the supply-demand[13] ratio, so as to make it manageable and bring it closer to an equilibrium. As illustrated by Figure 36, all these efforts might be insufficient to fully restore the balance, in which case the group of farmers dependent on the PS will face structural water shortage. Such a situation is likely to bring about changes in the choice of cropping patterns, with a wider adoption of crops with lower water requirements. However, one has to remember that most of the land in the Meet Yazid canal command area, most particularly north of the city of Kafr el Sheikh, needs to be periodically leached through the cultivation of rice (one year out of three, or every second year, at a minimum, depending on the area).

Two important remarks must be added with regard to these strategies. The first one is that these adaptations *come at a cost* to farmers, which includes the financial costs of having an oversized pumping capacity but also the burden of having to manage several devices at different places. The second is that the *ability to adapt* is not uniform and depends on various contextual features:

- farmers' financial capacity
- physical features: a higher leaching requirement, an unfavorable topography, the possible direct access to a main or secondary drain, etc.
- social make-up: the capacity among farmers to improve collective action around the distribution of water

6.2 Acceptability of the project

Irrespective of whether they are available or not to farmers in a specific location, these different strategies are associated with a series of costs, some of them monetary (e.g. buying a new engine) and other non-monetary (e.g. transaction costs), some of them individual others collective. Costs associated with site-specific situations or project defects are magnified by the following conditions:

- design issues (too high inlet pipe; narrow distribution pipe; too low number of valves; poor quality of valves and hydrants; and above all the low capacity of the pumps)
- implementation problems (faulty canal profiles; poor compaction; leaking or broken pipes; unfinished work by the contractor; damage to the subsurface drains, etc.)
- difficulty to find spare parts and repair services for the motors and the pumps, as well as in case of damage to the buried piped network
- vulnerability to power cuts or diesel shortages
- thefts and security in general
- conflicts generated by the need for collective management

[13] 'Demand' is a partly relative concept in that it incorporates the intensity of managerial efforts which impacts the way by which theoretical crop water requirement translate into an overall 'demand'.

Figure 35. Categories of historical trajectories of IIP pump stations

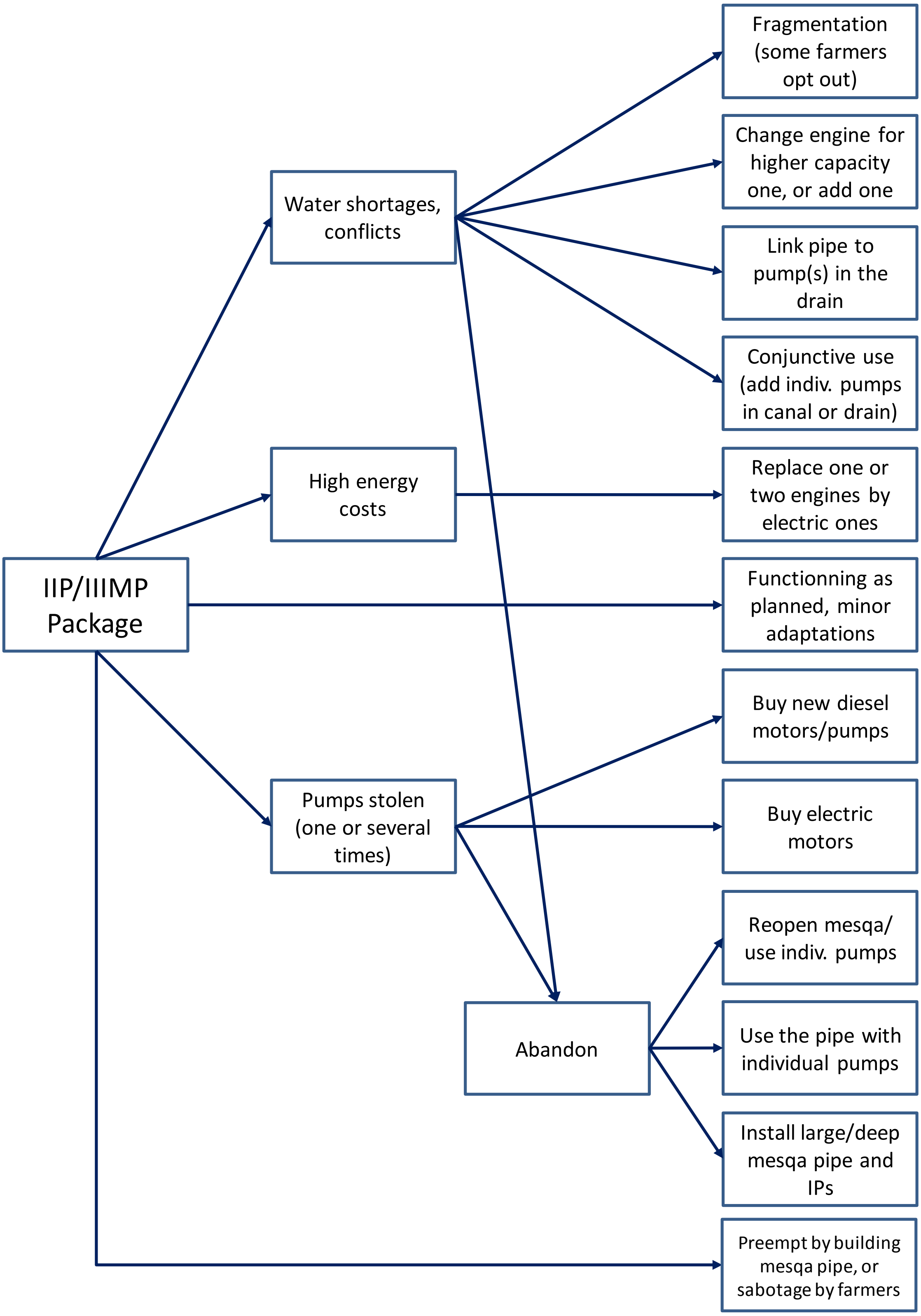


Figure 36. The supply-demand (im)balance in IIP stations

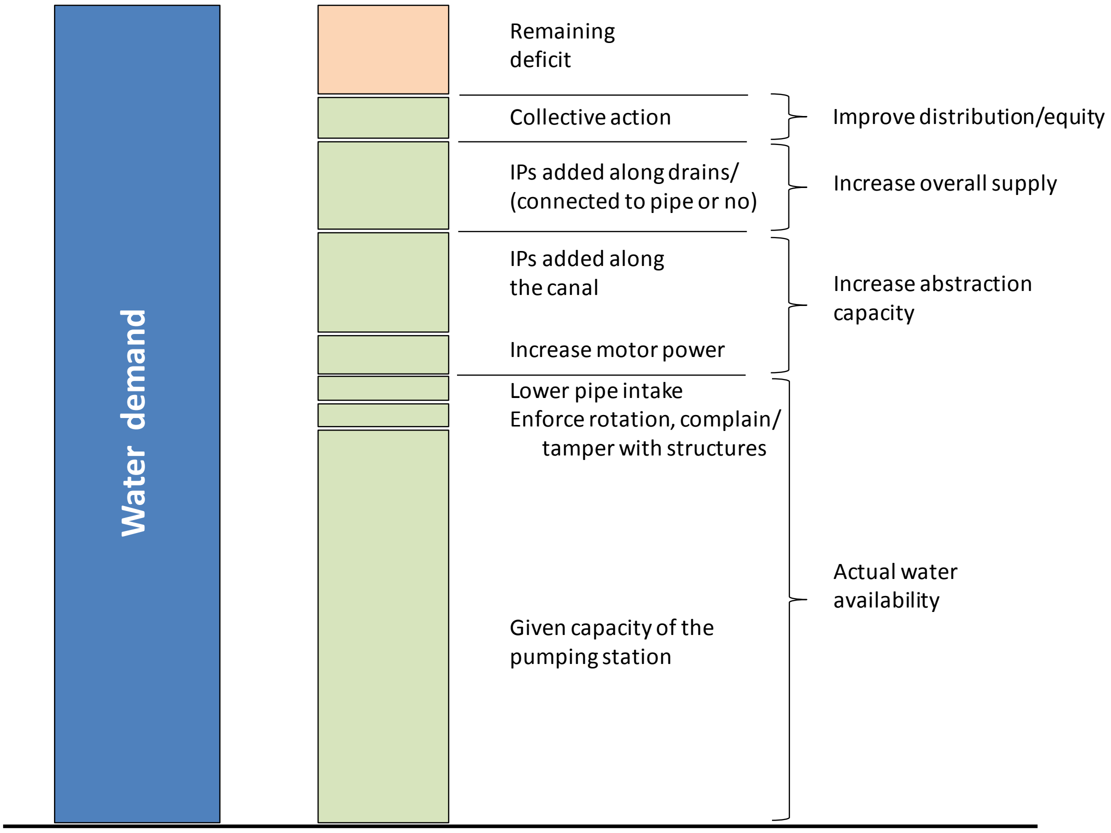
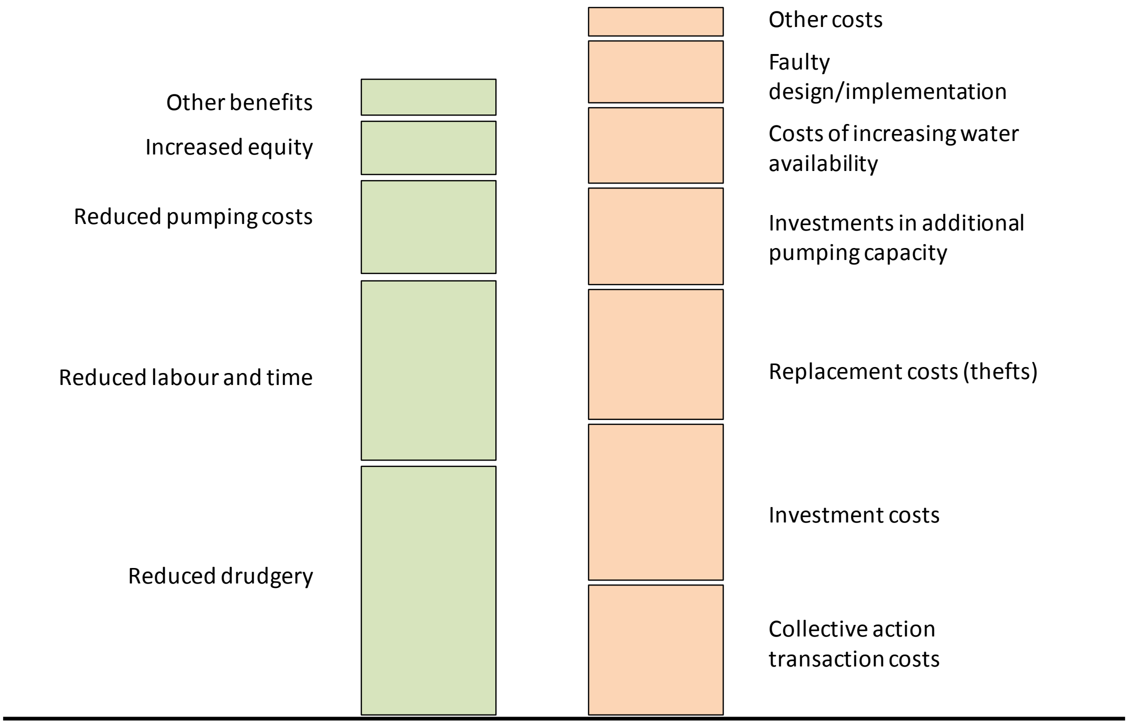


Figure 37. Balance between costs and benefits as perceived by farmers



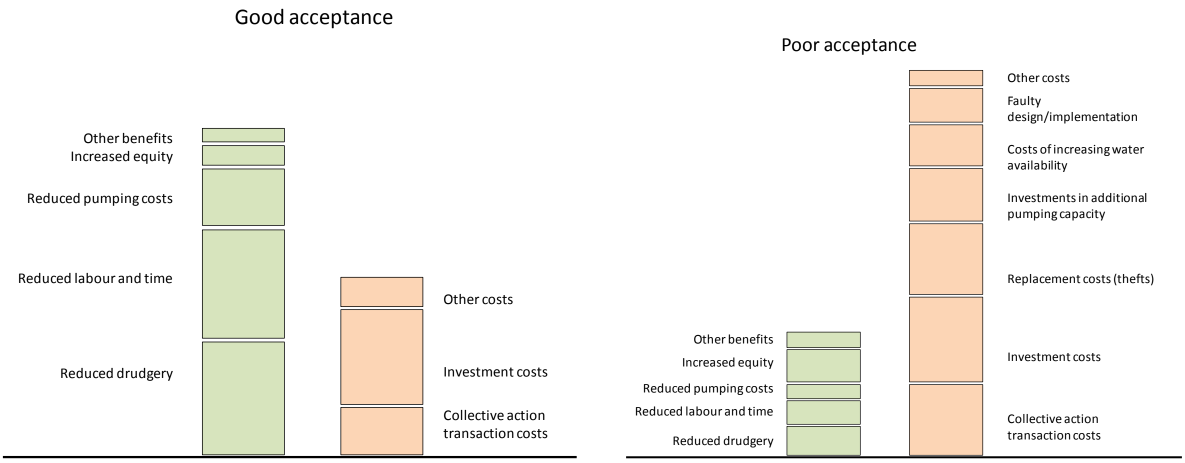
These costs are implicitly weighed against benefits, as shown in Figure 37. As discussed in Chapter 5, these chiefly include: 1) a better equity of distribution, 2) reduced pumping costs and time for irrigating, and 3) increased easiness of operation and water distribution.

Whether a particular farmer tends to be satisfied with the project or not depends on his/her *perception* of the balance of costs and benefits. It is important to emphasize that this perception is relative and depends both on the physical location of a farmer's plot, but also on personal characteristics like his income (e.g. if he is rich the financial burden will be less felt), his gender (e.g. women emphasize the benefit of irrigating through valves, which make the operation easier), or his/her personal perception of equity and drudgery, for example. As a result, these benefits are not uniformly distributed and equally perceived among farmers using the same pump station, who therefore individually tend to emphasize particular aspects that differ from one to the other, which may lead to contrasting opinions about the *tatweer* project.

It is apparent from the preceding discussion, that water availability is the key issue and is overwhelmingly mentioned by farmers, before the question of whether PS are beneficial or not. In other words, most concur that when water is sufficiently available, the PS may be effective in reducing irrigation time, labor and drudgery, and improve equity. Where and when this is not the case, the PS often restricts the amount of water that can be abstracted during the short period of water availability and therefore leads to conflicts, fragmentation of groups, conjunctive use of canal and drainage water, and intensive use of individual pumps. Figure 38 (left) illustrates a situation in which the benefits clearly stick out, while the costs are minimal. If water is available in adequate quantities, then there is no need for incurring the costs of attempting to increase water availability and pumping capacity. In the opposite case (right), costs are magnified by the inadequacy of supply at the level of the pump station and the consequent need to look for solutions to cope with such a situation. Benefits, in turn, are not forthcoming because labor input and operational costs are not reduced when farmers have to abstract water from different sources. In such a case, of course, farmers' interest in *tatweer* itself is low (although at the individual level some may be better off, while for others the situation has worsened). If despite all adjustments the imbalance persists between supply and demand then *tatweer* forces farmers to pay for an investment that not only they often did not want but which make things worse. Such situations in particular can be found along the middle or terminal reach of many branch canals. Expectedly, this is also where a high proportion of abandoned pump stations can be observed (Figure 7).

The gradient of situations as governed by the overall water supply and other contextual factors mentioned earlier, is well illustrated by the Moheet canal, where IIIMP stations have been constructed in the past three years. As an upstream demonstration area for IIIMP, the water supply to this relatively small branch canal is good. The first station on this canal irrigates land belonging to one single (extended) family (10 members). There are two lines of distribution, with seven and two valves respectively. The pump station is near one house and the motors have therefore never been stolen. Water is available all the time, and if supply is discontinued it is for a maximum of two days. As a result there is no rotation, no organization for distribution, and all the members have the key of the pump station. They just deal with power cuts by waiting… and do not even have to bring their old diesel pumps to the canal side. As illustrated in Figure 38 (left), these farmers enjoy the benefits of the pump station and bear minimal costs.

Figure 38. Cost-benefit balances in contrasting situations



Another station located a few hundred meters further downstream also experiences good water availability. It serves a bigger area of 54 feddan, and the motors have been stolen once. One farmer owns a large area of 14 feddan served by one of the four marwas fed by the pump station. This large land owner has authority and is the person who enforces water scheduling and delivery, and solves conflicts. There is no operator and each group under one of the four marwas has a key of the station. In summer they organize a rotation, with each marwa being granted 24 hrs so that they can generally irrigate the whole area in 4 days. All farmers still have their IPs set up in the four lifting points that they were using earlier. They use them in case of electricity cuts and sometimes for convenience if they want to irrigate before their turn.

Further down the canal, water availability is still acceptable but farmers have a stricter scheduling for distribution. Although the motors of the two pumps have been, the farmers only agreed to replace one, since many of them are tenants and the owners were not interested in paying for the replacement. Consequently, the use of individual pumps is quite intensive and some of them have been connected directly with the distribution pipe so that water can be injected into it. In the last reach of the canal water availability is limited to two days per 'on' period. There is an intensive parallel use of individual pumps in the branch canal but also along the drain, without which "they would die", according to farmers. Collective action is weak and conflicts are frequent.

Similar illustrations of head-end/tail-end differences are given by the problems created to, and by, the pump stations located at the end of El Monshah, Shalma and other long branch canals, and also by the fact that the last 1.5 km of Khawaled canal has not been equipped with pump stations, probably on account of the fact discussed here.

But acceptability, as illustrated several times earlier, is also related to the transaction costs associated with collective action. There are cases where personal or family conflicts or non-collaborative behaviors lead to the failure of the PS, although other locational and water availability parameters are more or less adequate. Although this factor is extremely important, it is very hard to predict since it mirrors the diversity of social relationships. This is why taking greater care of involving concerned farmers when designing pump stations is paramount.

When trying to measure and anticipate the desirability of a particular project, economists conventionally compare financial costs with a number of expected benefits that they try to express in monetary terms. With regard to the project considered here, monetary benefits attached to the expected water savings, decrease in pumping and labor costs, and increase in equity, cultivated area and yields have been quantified at the feasibility and planning stages; and compared with the proportion of the financial monetary costs that were to be recovered by farmers and the state (World Bank 1994).

If we look at this economic exercise with the benefit of hindsight, we can make the following observations:

- Water savings and increases in yields have not been forthcoming for the reasons that have been discussed earlier.
- The decrease in pumping costs is limited, at least often unclear, for IIP stations with diesel pumps, but well identified in PS powered by electricity (with a cut of at least one third of the pumping costs when shifting from diesel to electricity)
- However, this financial benefit, although not negligible, is quite limited in terms of magnitude, since its represent only around 50 EGP/feddan per season.
- The benefit is even less clear when the cost of the new electric motor(s) and of the connection and transformer is factored in. With an investment of, say, around 500 EGP/fed - as an order of magnitude– the initial cost represents 5 years of savings in the energy bill.
- The gains in the cultivated area, although not formally assessed by our survey, were found to be limited, on account of the fact that in most instances the area of the mesqa was left uncultivated after being filled in.
- Likewise the gains in terms of labor costs are extremely hard to assess and are predicated upon the hypothesis that reduced labor time would be used productively in another economic activity. On the face of it, we found this hypothesis optimistic and could not find much anecdotic support for it, with a single exception of its mention by a farmer.

As a result, the (monetized) benefits from the project can be safely said to be less than the projections and, as is often the case, the initial hypotheses appear to have been overly optimistic. But this conclusion comes with three additional important, and for the latter two, somewhat surprising, observations:

- First, the project has glossed over the transaction costs of collective action. Since these costs are not easily monetized it is tempting to avoid considering what it will take for a group of farmers to fulfill all the tasks associated with operating and maintaining a collective pump station. While for some groups these costs are very limited (sometimes everyone has the key and there isn't even an operator), for others they include a lot of transaction costs generated by tensions and conflicts.
- Second, the overwhelming majority of farmers did not know how much they would have to pay annually, and for how long, for the *tatweer* investment. More surprisingly, the financial burden corresponding to the imposition of this payment was very seldom mentioned by farmers as a cause of great dissatisfaction. We should not jump too quickly, however, to the conclusion that the financial effort requested is limited, and easily absorbed by the farmers (although a substantial number of farmers' revenue is raised by non-farm activities and overseas remittances). This attitude, among other things, also reflects the passivity in the front of government projects and initiatives that routinely translate into an increase in the overall tax that is collected by the land tax collector. Further, it might reflect the fact that farmers are aware that earlier beneficiaries are not necessarily paying, and that they might be intending to do the same.
- Third, and on the other hand, one of the main satisfactions expressed by farmers referred to the *decrease in drudgery*, that is, the reduction of the burden of carrying out a number of

tasks, such as moving individual pumps around, having to take off one's clothes to get down in the mud/filth of the mesqa to set up the suction hose, staying long hours in the fields to monitor the progress of water, bringing diesel jerry cans to the field, etc. Drudgery is also a very personal perception, which varies with factors such as age, gender, health, pluri-activity, interest in farming, etc.

All in all, this translates an overall feeling from the many interviews held with farmers that the formal cost-benefit analysis carried out by project planners is of little relevance and that farmers are, under certain conditions, eventually ready to accept and/or pay for a technical innovation that may bring few of the benefits expected but which substantially decreases the drudgery of irrigation at tertiary and farm levels. This conclusion provides a very strong indication that collective (electric or mixed diesel/electric) pump stations, even stripped of promises of continuous flow and other benefits, could be proposed *'on-demand'*, with farmers sorting out whether their particular conditions (including location within the distribution system, physical characteristics, investment capacity, social cohesion, etc.) make such an investment *desirable* according to their particular way of valuing and perceiving costs and benefits. This desirability is expected, in many cases, to owe little to a conventional economic analysis and to reflect a number of personal and social perceptions and local conditions. There is no single universal method to determine what is a rational solution and an 'improvement' for farmers in particular situations.

An additional comment must be made here on the relevance of economic analysis, as conducted by development banks. Because of the formal importance of coming up with adequate internal rates of return, both for the financing and the evaluation of development projects, the soundness of technical options and the quality of the material employed in construction is sometimes negatively affected by the excessive weight given to economic analysis. The most blatant illustration of that fact is the unfortunate reduction in the quality and the diameter of the PVC pipes used in marwa improvement projects, which has been driven by the will to cut costs in order to improve the formal economic viability of the project. This has resulted in countless defects and failures in the on-farm distribution systems of IIIMP projects that have angered farmers, even though they would have much preferred to pay an additional, say 10-15%, to have a project implemented with good quality material.

Our emphasis here is on the fact that such conditions, not least the social structure and cohesion of farmers as a group, are not easily assessed by, an often not accessible to, top-down projects with a natural tendency -because of constraints of time, money, and information– to be blind to the complexity of both the social and the environmental realms, and to apply blueprints in a uniform manner.

Given the importance of the relative values of supply and demand at the pump station level, we must question the suitability of developing IIIMP pump stations in the downstream reach of long canals like Halafy, El-Ghabat or Daramally. Because water availability typically varies between 1 to 3 days, establishing stations designed to work under conditions of continuously available flow is a sure recipe to disaster, especially with the reduced per hectare capacity of IIIMP pumps. The experience in the downstream reaches of branch canals in the Sidi Salem district (Manshaqa, Khawaled, Shalma, etc.) and Bosees, despite the more generous design criteria that were used by IIP at the time, is not supportive of such an expansion.

Probably not by chance, implementation of IIIMP in the Meet Yazid area has initially been concentrated in upstream areas or in branch canals (Mares el Gamal, Moheet) with relatively good water supply. The few IIIMP pump stations constructed so far in the mid and downstream part of El Halafy canal are waiting for their electricity connection, with a few exceptions. Nevertheless, it is apparent that four aspects are making the project so far attractive to the farmers who have accepted it:

1. the transformation of the former long mesqas into piped mesqas, with the expectation that water distribution will be eased;
2. the electrification of pumping (with lower unit costs);
3. the optional addition of a diesel pump incorporated in the pump station;
4. the possibility to keep the former pump sump and its individual pumps in place (see Figure 39).

All this contributes to increasing the pumping capacity and the ease for these farmer groups and as a result is seen by many as a positive change worth an investment.

Figure 39. IIIMP pump stations in Halafy canal command area

The pump stations includes two electric pumps and one diesel pump; the pump sump is maintained (in the back)		The pump station (back) delivers water to a pipe that parallels the existing marwas. The pumps sump is also supplied	

It is too early to know how these assumptions will work out but a few observations can be made. By increasing the pumping capacity of farmers, the project is likely to worsen the equity of distribution both within the mesqas, and between mesqas. Piped mesqas are being constructed with a slope that favors the flow of water to its downstream part. One contractor believed that this might even play in favor of downstream users, but the experience from one of these mesqas, where two PS had received their electricity connection and were working at the end of the line, suggests that it is too early to share such optimism. These two pumps, in one of the visits paid in late June 2014, were reported to have caused some fighting between farmers, due to the insufficient quantity of water they were able to access. The interaction between mesqas, and whether the downstream ones will be further impacted by a possible increase in pumping capacity of the upstream mesqas, is yet to be observed after implementation is concluded.

The opinion of the presidents of the Branch Canal Water User Associations of Hag Yussef (downstream reach of El Halafi) and Daramaly (sub-branch of El Halafi) respectively on the proposed IIIMP improvement can be mentioned with respect to this debate. The head of the former is convinced that the development of collective pump station in the upstream reach of El Halafi will reduce water abstraction and be beneficial to downstream farmers, who should also adopt *tatweer*. They have negotiated with IIIMP to have pump stations serving 30 feddan (and 6 farmers), and equipped with pumps of 90 l/s capacity (this is more than three times the design value but is justified by the will to buy farmers in). The head of the latter, in contrast, has agitated against IIIMP and even taken legal steps to prevent any investment along the last 4.5 km of the canal. He explained that what they need is not to shift from individual to collective pumps but, rather, to get small water in the first place. As a result, they are moving to piping their mesqa, as proposed by a local entrepreneur (see section 3.2.1.4). These hopes and fears are based on opposite readings of how *tatweer* modifies water availability (or not).

Electrification of PS through a dedicated line (as implemented by IIIMP) offers the potential to control abstraction by cutting energy supply, a solution implemented in some states of India to control groundwater abstraction (Shah 2009). Although there is no such established policy (nor legal justification to do this), we have found two instances where managers had resorted occasionally to this solution. This could be a powerful tool to better enforce rotational schedules along branch canals, but existence of a parallel pumping capacity through collective diesel pumps and IPs works against this.

6.3 Pathways to improved implementation

Considering the necessity of better tailoring the technical improvements proposed to the diversity of social and physical contexts, this section suggests some areas in which improvements are desirable and can be achieved.

Design: the benefits expected from IIP implementation were largely linked to the promise of a continuous flow in the branch canals. Under the assumption that the water would be available all the time, the pump stations were designed to be able to serve the whole area at the time of peak water requirements with a daily operation time of 16 hours (a number of hours that was to be increased to 20 hours in W10 and IIIMP areas). But continuous flow is still not forthcoming and pump stations along branch canals face a rotational schedule, where water availability in most cases ranges between 1 to 4 days a week (see IWMI-WMRI report No. 1, 2013). The generous design capacity of IIP pumps (1.14 l/s/fed in theory but around 2 l/s/fed in practice, especially for PS serving areas under 60 fed, *partly* compensated for the non-realization of continuous flow and the limited number of days with water availability[14], but not fully, as indicated by widespread conjunctive use. Stricter design capacities adopted for IIIMP (0.84 l/s/fed) increase the likelihood of mismatch between the amount of water the station is able to deliver and farmers' demand.

This sheer discrepancy between the design and the actual durations of water availability easily explains the various efforts by farmers to rebalance the supply-demand ratio. A consequence of this observation is that the implementation of IIP pump stations might be best reserved to the upstream reaches of branch canals with a relatively good and secure supply. Conversely it should be avoided at the tail end of long branch canals where, under present circumstances, it is not possible to make water available during a time long enough to allow the benefits of the pump station to materialize.

In order not to favor upstream farmers by increasing their overall pumping capacity (while at the same time impacting downstream farmers), it is advisable to keep close to the design capacity of the pumps and remove IP pump sumps. But of course there is a fine trade-off between making the project attractive and desirable for the farmers and respecting strict criteria on installed pumping capacity so that equity of water distribution between PS/mesqas is not affected. There is an overall feeling that at the moment IIIMP, in its bargaining with farmers, has to be quite lenient and flexible regarding large pumping capacities and the non-removal of IPs (especially because, in the latter case, the occurrence of frequent electricity cuts justify maintaining IPs).

Last, it is clear from the survey that successful pump stations are in most cases smaller pump stations, serving an area between 25 and 40 feddan. This suggests that smaller pumps are more sustainable and more easily accepted and managed by farmers, even if some stations with large

[14] Pump units of 30 l/s were eventually replaced by 60 l/s, a 'security margin' of 30 l/s was added.

areas (more than 100 feddan) may occasionally work well. This lesson has been incorporated in IIIMP, where the average served area is much smaller than for IIP.

Implementation: a number of issues related to implementation have also surfaced during the survey. By and large these are issues that have already been identified and discussed in earlier IIP reports, but presumably not entirely solved. The first one is the need to increase the involvement and participation of farmers in the design and implementation of the pump stations and their networks. Several farmers reported having engaged with IIS/IAS engineers to discuss issues such as the location of the pump station, pumping capacity, the number and the location of the valves, and more importantly the size and boundaries of the distribution area. In some cases negotiations have allowed to identify a commonly agreed solution, while in many others the design was imposed. In other cases farmers' hostility prevented the implementation of the project.

On the positive side, we have identified occasions where engineers or contractors were willing to discuss the design and implementation of improvements with farmers, designed an internal rotation with farmers for their pump station, and provided some on-the-spot training to them. It is clear that IIIMP is implemented with much more flexibility than IIP. In the same area of Mares el Gamal, however, stand two contrasting cases: in the first one farmers have obtained a more ramified network with a large number of valves, while in the other the engineers have imposed short pipes and farmers at the end of the area still use their open marwas and wait for half an hour for water to reach their field, which defeats the interest of the project.

The general impression in IIIMP areas with recent implementation is that farmers are frequently not clear about how much they will have to pay, when this will start, and for how long. While in some cases this might be interpreted as a way for farmers to stress that they would have liked to be more substantially involved, it does show that the information delivered during the meetings is not very specific: because costs vary between PS and because the final design may differ from the one proposed, engineers are reluctant to come up with any numbers, for fear that farmers would later refuse to pay possibly higher amounts, or generate conflicts about that. It should be possible however to announce a very clear *range* to farmers from the onset, and explain why the cost is not fully determined. Such clarity would help farmers take a decision on whether they agree to have the project implemented, and would contribute to building trust. For lack of data we could not clarify to what extent farmers are actually paying for the improvements, and therefore *to what extent their acceptance of the project is influenced by the perception that they might escape repayment*.

'Guarantee': Another issue, identified from the beginning of the IIP project in the mid-90s, is the unsatisfactory performance of some contractors. Farmers do not have the capacity to fully test the quality of the works at the reception of the works, and in some cases are left with faulty installations that create hardships and additional costs to them. This can involve the pipe between the branch canal and the pumping pit, the level or the valve of the suction pipe, the material used to protect and burry the pipe in the trench, electricity wiring, etc. Problems can materialize from the start or within a few months or a couple of years problems, in particular with both the valves and the buried pipes.

In IIIMP projects the reduction in the quality of the pipes (reduced thickness) has resulted in frequent breaking of the pipes (notably when compaction was not done properly and heavy equipment like tractors pass over the trenches), leakage at the level of the junctions between the pipe and the vertical outlets to the valves (T junction), and leakage at the level of the valves themselves (see Figure 34).

At present the contractor has the obligation to intervene during one year after reception of the works by farmers in case of leakage at the level of the distribution pipe. The same applies to piped marwas but not to hydrants. At least a few cases indicate that obtaining repairs for marwa pipes may be frustrating.

Some cases seem to fall in a grey zone: in Mares el Gamal a small electric pump station was officially received by farmers and functioned during one month. The station is connected to a local transformer through a 350 m cable buried 30 cm under the ground surface, a technical solution for which the farmers opted, but engineers had advised against. After this a problem in the cable occurred which interrupted the electric supply of the pump station. It is not clear what exactly caused that problem and where. Farmers made countless visits to Tanta and Kafr el Sheikh IIIMP offices but there complaint was not acted upon, possibly on account of the fact that the station had been officially received and that the problem was deemed to be independent from the responsibility of the electricity company or IIIMP. Farmers were left without the technical capacity to identify where and what the problem is, with a station that they have to pay for and which has been working only one month, in addition to which they had to buy a diesel engine to be able to irrigate. Tension ran high, with farmers talking of destroying the whole investment and reverting back to their individual pumps. The connection problem was temporarily solved by the intervention of the electricity company, but then happened again repeatedly[15]. However, farmers more in general in this improved area continued to be troubled by frequent and long power cuts. The visit to the IIIMP office also showed that dedicated IIIMP engineers are receiving many of such service requests (often related to improper construction), which they cannot attend since their institutional focus is on finishing and delivery of new PS. These kind of technical problems that occur after reception are many and often left unattended within the current bureaucratic set-up. This is one of many examples of an investment threatened to be obliterated for lack of an effective mechanism to address technical failures.

One must also mention the numerous additional small problems that are experienced after construction and are never fixed by contractors. Although these problems may appear minor they make farmers angry because they have the feeling that their complaints are disregarded and the tool creates unnecessary nuisance or harm to villagers. These include leaking escape valves (which slowly destroy the wall of the pump house), pumping pits that are left without cover (and constitute a danger for small children), electric connections that are not correctly buried and may also offer a danger to children playing in the area, digital screens indicating electricity consumption that are not working, 'keys' provided to open/close the main valves that break easily because of poor quality, and various other types of unfinished work (Figure 40).

'After-sales service': More generally there are numerous complaints from farmers about the lack of support and after-sales service. While electric motors can be found in bigger cities, such as Mansoura, farmers do not always have easy access to specialized technicians or workshops which can repair or manufacture spare parts, carry out heavier interventions such as repair of leaking or broken pipes, or checking the defects in electric wiring (see above). Although in some instances local workshops have been able to manufacture (alfalfa) valves, sometimes of different types, and although some farmers mentioned having gone to Shubra to get original parts from IIP, it would be appropriate to train and support some local and independent entrepreneurs who could be equipped to deliver all types of maintenance services and spare parts related to *tatweer* investments, from the electric transformers down to the farm level hydrants. It is recommended that these local workshops should be set up independently from the bureaucratic structure of the Improvement Sector, although it would require their technical supervision.

[15] Intervention by IWMI-WMRI at the IIIMP office in Tanta, enabled the partial replacement of the electricity cable, which unfortunately also did not entirely solve the problem, but later interventions in the end did.

We have also found several cases of pump stations that had been partly implemented on the ground but not completed because of conflicts between farmers. *A mechanism should be found to solve such conflicts in order to avoid the loss of investment.* NGOs could, for example, be contracted to mediate such conflicting situations.

Figure 40. Example of unfinished work harming farmers

Open pit	Loose electric connection	Unfinished work
		
Leaking escape valves	Broken keys	
		

Theft: An extremely serious problem experienced by *tatweer* is that of theft. It appeared that the canal reaches where engines have been stolen on a large scale are in general distant from villages and therefore very vulnerable to visits by thieves at night. Implementation in such areas might not be given priority.

Alternatively, it might be possible to think of structural devices which would make the removal of the engines difficult, if not impossible. Farmers have shown the way by coming up with very creative ideas about how to hinder and prevent theft.

Zoning: Given the wide range of situations mentioned above, from successful implementation to the abandonment of pump stations, it is advisable to carry out a preliminary zoning in which favorable areas where the likelihood of success and farmers satisfaction is higher would be identified. It is quite clear from our survey that it is advisable to avoid the terminal reaches of long canals, areas with very limited supply, or unprotected areas vulnerable to thefts.

By focusing on favorable areas, picking up first the low hanging fruits, IIIMP would maximize the rate of success of its collective pump stations and would gradually change the overall perception of the project by farmers, making it more attractive. This is implicitly what IIIMP has done by starting with small branch canals (El Moheet, Khadega, etc.) or longer ones with rather good supply (e.g. Mares El Gamal). In contrast, the current extension of the project to the downstream area of El Halafi canal (and more generally Sidi Ghazi district) is worrying because of the much less favorable availability of water in this area. A zoning, however, would still be unable to capture the full diversity of social contexts, which requires detailed contextual knowledge, and it is thus more advisable to adopt an 'on-demand policy'.

On-demand policy: *There remains a lot of uncertainty on the balance of costs and benefits for particular farmers and group of farmers in different locations, as it is hard to predict the cumulative effects of improvement projects both at the branch canal level and in particular mesqas*. As indicated earlier, we found that there is a sufficient demand for both collective pumps and marwa improvement to envisage projects which would be made increasingly on-demand and would offer a diversity of interventions. This suggestion was already made in 1998 by IRG et al. (1998a). Two particular experiences observed in the field are worth being mentioned here.

A group of 71 farmers owning an area of 170 feddan along the upstream reach of the Shalma canal, were not considered by IIP because their land was too far and too high to be served by a PS available under IIP. Their area was served by a 1 km long mesqa, with a main lifting point located at the end. They hadtanbur to use two tractors with *tanbur* pumps at the head of the mesqa in order to speed up and fill it up with water in case of low water levels. In this situation a part of these high lands could not be cultivated and yields were very low. One of the members reported to have besieged the Improvement Sector during several years before he met an IIIMP engineer from the area who listened to him. The pump station designed and installed by IIIMP has three electric pumps, to which two big diesel pumps have been added. In addition to the distribution network and pumps themselves they had to pay for an electricity connection and for buying the land of the pipe and the station. At the end the cost was around 10,000 EGP per feddan, which is relatively high. This is an example of demand-driven costly project which farmers said they were happy to pay for because in the earlier situation they just could not cultivate at all, and yields were very low (this also significantly increased the productive potential and the market value of their land.

Figure 41. On-demand IIIMP special project

The pump station includes three electric pumps and two diesel pumps		The two diesel pumps have been added on the side of the pump house, and a wall has been added to protect them	

Another example of on-demand adaptation of IIIMP design is provided by a contractor working in the Bashair canal. Instead of one main pipeline equipped with seven valves serving marwas, farmers have asked for lateral branches in the fashion of the marwa pipes but of a bigger size and with a larger number of valves (which, in that case, almost serve as field-level hydrants). This is a type of *hybrid* between IIIMP and FIMP/OFIDO marwa development projects. This special design has been agreed by the farmers and the IIS/contractors after a conflict that had delayed works. The additional cost, estimated at 500 EGP/fed (that is an increase from 4000 to 4500 EGP/fed), will be borne by the farmers who have obtained a distribution network that conforms to their requirements and requests.

These two examples show that it is possible to adapt the technical improvements at the design stage, so that it incorporates specific requests made by farmers. These requests reflect a number of local specificities regarding, for example, soil type, topography of plot size, but also regarding social conditions: farmers not willing to share a valve because of conflicts, for example; or the other way around, as seen in one IIIMP station in Moheet canal, where a farmer with several plots preferred to have one single main valve for him, rather than several hydrants (one for each plot). Since the costs charged to farmers are individualized, based on their specific requests and requirements, this does not raise objections from neighbors. And the satisfaction of these requests strongly helps to increase the satisfaction of farmers and the sustainability of the investment. The IIS engineers have to ensure the overall technical feasibility and consistency of the requested changes.

From the analysis conducted for this report, it is anticipated that requests for projects would most probably chiefly come from areas with the following conditions:

- areas along the main canals or along the head reach of branch canals, that have reasonable access to water
- areas that are distant from the branch canal and without access to drains; farmers with land adjacent to the branch canal and not interested in a collective pump could simply not join the group.
- areas located close to a house or a village, so that theft is made more difficult.
- areas with a higher elevation
- one could expect a preference for small pump stations, typically serving between 25 and 40 feddans, which would be managed by a small group of farmers with good relationships and who *would have chosen* to share the investment and the undertaking.

An 'on-demand' mode of operation would probably be a bit more costly for contractors (and farmers), who would have to move equipment to more spatially scattered spots rather than along one given canal. But there are very clear indications that in most cases farmers are ready to face the corresponding additional costs.

Another difficulty would come from the electrification component, which cannot be put in place for one or two pump stations only. IIS would therefore have to conduct a preliminary survey of different canal reaches to identify the level of the demand.

Crucially, the design capacity of the pumps, but also of the distribution pipe, *would have to be kept within certain technical limits, to prevent the emergence of collective pumps with very high abstraction capacity*, which would impact downstream areas.

More generally, the conclusions of this report argue for a more flexible approach to irrigation improvement in the Nile Delta. Instead of proposing a one-fit-all technical innovation, the Irrigation Improvement Sector could not only make its projects on-demand but also enlarge its offer and consider proposing other types of interventions, as is the case with the on-farm development projects (OFIDO, FIMP, etc.). This would have to be made in collaboration with the ministry of agriculture, who is responsible for on-farm improvement projects. These interventions, which would be requested by, and paid for, by farmers, could include:

- On-farm interventions, such as laser leveling or de-clogging of subsurface drainage, already proposed by other sectors or projects.
- interventions at the level of the inlet pipe, to lower its level in order to improve access to water, when this is necessary.
- a shift from diesel pumps to electric pumps (this is already made possible by contracts between farmers and the electricity authorities).
- a range of solutions to line or turn (long) marwas into brick/concrete canals (such projects were implemented in the past by the ministry of agriculture), and as frequently implemented by the farmers themselves (Figure 42).

- replacement of the open mesqa by large covered concrete pipes, with openings for farmers to abstract water individually, as they do in earthen mesqas. This locally developed innovation is already taking place in an informal way, as discussed earlier, and might well be better adapted to the downstream reaches of the branch canals.
- IIIMP collective stations, with more flexibility about technical options (electric motors, or mixed electric and diesel stations; number and position of valves; inlet at the end of the main pipe to allow the connection with a pump located in the nearby drain, when this is the case; etc.)
- it has already been made possible by IIIMP for farmers to buy an additional diesel engine. Until recently it had to be fit outside of the pump stations and was therefore not protected. An alternative and optional design of the pump station has now been proposed by IIIMP, with the additional diesel engine being also placed within the (enlarged) station, and therefore protected. This is a good example of optional design, with additional costs made clear and charged to farmers.

Figure 42. Locally made marwa improvements

In that sense one could envisage a transition from a 'project-based' mode of implementation by the ministry to a situation where a number of accredited small companies would propose different types of improvement, including collective pumps.

However it is clear that a degree of supervision by the Irrigation Improvement Sector of the ministry is necessary. The ministry formerly regulated water abstraction by limiting the intake of mesqas, a limitation that led many farmers to remove or alter the inlet structures, this control has been largely lost. However, it is still crucial to ensure that specific groups of farmers do not develop excessive abstraction capacity, as discussed in the preceding section. IIS would either be in charge of design (as is the case at present), or revise the design options and characteristics of the projects, to make sure they are compatible with the necessity to control and distribute the overall pumping capacity along the branch canals.

7 Conclusions

In the last three decades, irrigation improvement projects in Egypt have been tested, implemented, developed and modified in an attempt to respond to a number of identified constraints in irrigation water management. They have proposed interventions concerning the branch canal level (continuous flow, automatic gates, branch canal water user associations), the mesqa level (collective pump stations and WUAs), and the on-farm or marwa level (distribution networks down to the plot). This report draws lessons from surveys conducted in the Meet Yazid canal command area regarding IIP and IIIMP pump stations, with additional observations on on-farm interventions. It reveals a reality that is frequently quite remote from theoretical design and the benefits expected at the onset, when it was posited that "the IIP is to be understood as a model for the way the government wishes to bring the Egyptian irrigation system in line with demands it will be facing by the turn-of-the-century" (Hvidt, 1988).

1. The failure to implement *continuous flow*, "the key and lead technology of IIP" (IRG et al., 1998), has been dealt with through the continued and rather self-serving assumption that it would take time to operationalize it. There has been no attempt to revisit the project assumptions and rationale of IIIMP in case continuous flow would not be forthcoming.

It is also not clear whether the lessons of the failure of downstream regulation -currently not a single automatic gate set up in the Meet Yazid command area is functioning– have been taken to their logical conclusion. In particular with regard to what should be done with the structures in place, which are not working but obstructing the flow. But it is noted that IIIMP has gone forward while canceling technical interventions at the level of the branch canal and abandoning continuous flow.

2. The establishment of *Water User Associations* was a cornerstone of the improvement projects, partly because of the intent expressed in the project documents to increase participation of farmers in the design of the improvement itself, as well as in the management of water at the branch canal level. WUAs were expected to be the recipients of communication campaigns and trainings that would allow them to acquire the skills necessary to manage and maintain their collective pumps as well as corresponding financial aspects. Both the revision of the 1984 Law (in 1994) and project documents had established very detailed regulations and instructions about what these associations were expected to do and how they should function.

The survey has revealed a large discrepancy between these formal expectations and reality on the ground. The very existence of a collective pump station makes it inevitable to have a degree of collective organization around a device that needs to be managed in a sustainable way. Most farmers, however, did not consider themselves as 'members' of the Association and pointed to the initially designated, rather than formally elected, board members as the Association's members.

The respective roles of the president, secretary and treasurer of the association, when these existed or had any distinctive activity, were quite different from the roles indicated in the regulations. Local practices in terms of meetings, decision-making, water management rules, or collection of fees were found to be extremely varied and to reflect local environmental, technical and social conditions (size of the group, area and shape of the command irrigated, position within the branch canal, overall collective and individual pumping capacity, filled in mesqa or parallel mesqa, social cohesion, etc.).

3. Although *Branch Canal Water User Associations* have been formally established in all branch canals, they were found to be by and large non-active in the operation and maintenance of branch canals. In some cases promises have been made about the establishment of an office, or about the power that these Associations would have in deciding maintenance work and checking their quality

at the end of their execution, for example. Since these associations were not really empowered, their board members manifest some frustration regarding this experience. Most farmers ignored the existence of the associations.[16]

4. *Participation of farmers in the design* of the improvement has been low. While in some cases farmers have been involved in decisions regarding the number and the position of the valves, for example, in many others the design options have been imposed and the suggestions of farmers disregarded. Likewise, while some individuals or group of farmers have been able to refuse the project, many more felt that it was imposed and that they did not have the possibility to refuse it. The latter case was more frequent in the earlier phases of IIP. Practices of the IIIMP project seem to have improved in this respect.

5. *Water management rules at the pump station level* are in general only agreed upon and applied during the peak of demand in summer, while in the remaining of the year the system is more or less on-demand, with farmers making their request directly to the pump operator. During summer, farmers typically divide their area in sections (defined by a given number of valves), and establish a rotation between these sections with a given number of hours for each of them. In many cases each feddan will then have a fixed time for its irrigation (typically 1.0-1.5 hour). The total duration of one full rotation has of course to be compatible with the expected time water will be available in front of the pump station. The rules must be adjusted when water is still available after the full rotation, when some farmers have not been served, or when distribution is interrupted by a power cut or a mechanical problem.

6. The detailed analysis of IIP/IIIMP pump stations has revealed a very large diversity of situations, ranging from ones where the pump stations are used to the satisfaction of farmers since the beginning, to others where they have created conflicts or been abandoned altogether. The most striking observation is that *few* pump stations are working with the initial pumps, engines, design areas, and target farmers that were present at the time of implementation. This is not necessarily a problem, as it shows in part that farmers are innovative and able to 'reshape' a given technological innovation to fit local conditions.

This report has described the evolution of PS *'trajectories'*, revealing a number of strategies (which occur simultaneously or sequentially), that fall under five categories: 1) efforts to increase supply availability at the pump level; 2) increasing the abstraction capacity; 3) increasing supply by tapping other sources; 4) improving internal management rules; 5) abandoning the pump station and reverting to individual pumps, sometimes after installing a large diameter pipe to serve as mesqa. 18% of the PS were found to be out of order. In most cases (16% of the total) pump houses were empty, and in a few cases the motors could be seen but were not in working order.

Out of a total of 1288 initial diesel pumps of the 640 PS surveyed, we found 890 diesel pumps (of which 812 were working) and 288 electric pumps (approximately one fourth of the stations). *Electrification* has been popular among farmers, largely because it is cheaper and less burdensome than diesel. However, they often choose to combine electric and diesel pumps, in view of energy supply cuts.

7. *Electrification*. It should be noted that electrification of PS through a dedicated line (as implemented by IIIMP) offers the potential to control abstraction by cutting energy supply; we have found two instances where managers had resorted occasionally to this solution, which could be a

[16] See IWMI-WMRI report No. 8 '*Branch Canal Water User Associations in the Central Nile Delta*'.

powerful tool to better enforce rotational schedules along branch canals, although the tendency to parallel the pumping capacity with a collective diesel pumps (let alone IPs) works against this.

8. Whether a particular farmer tends to be satisfied with the project or not depends on his/her *perception* of the balance of costs (eg: transaction costs of collective action; replacement cost of stolen motors; investments in a additional pumping capacity; costs of increasing water availability, likelihood that costs will have to be recovered, etc.) and benefits (reduced pumping costs, labor, and drudgery; increased equity, etc.). This perception is relative and the valuation is subjective and depends both on the physical location of a farmer's plot, but also on personal characteristics like income, gender, and personal perception of equity and drudgery, for example.

These costs are implicitly weighed against benefits, as shown in Figure 37. As discussed in Chapter 5, these chiefly include: 1) a better equity of distribution, 2) reduced pumping costs and time for irrigating, and 3) increased easiness of operation and water distribution.

While some pump stations have been working for many years with only minor problems, too many others have been bedeviled by a number of flaws and shortcomings. These include *design issues* (too high inlet pipe; narrow distribution pipe; too low number of valves; poor quality of valves and hydrants; and above all a low capacity of the pumps); *implementation problems* (faulty canal profiles; poor compaction; leaking or broken pipes; unfinished work by the contractor; damage to the subsurface drains, etc.), let alone wider issues related to power cuts or diesel shortages, or thefts and security in general.

9. *The availability of water in the branch canal* is the key issue and is overwhelmingly mentioned by farmers, before the question of whether PS are a good idea or not. In other words, most concur that when water is available in sufficient quantities, the PS may express their potential in terms of reduction in irrigation time, reduction in labor, and better equity. On the other hand, where and when this is not the case, the PS restricts the amount of water that can be abstracted during the short period of water availability. This then leads to conflicts, fragmentation of groups, conjunctive use of canal and drainage water, and intensive use of individual pumps.

10. *Maintenance* needs include running expenditures (e.g. oil for the motors), that are taken care of through the money collected each season from the farmers, and exceptional repairs/ improvements (severe breakdown of the motor; stolen pump that has to be replaced; electrification of the pump station). These give way to a collective decision-making followed by the collection of an ad-hoc per feddan contribution. Financial management in general does not seem to be a big problem or to generate lasting conflicts.

11. *Changes in water savings, crop yields or cropping patterns* could not be evidenced from our casual observations as well as from more detailed monitoring and evaluation activities. It was also not obvious that land savings had resulted from mesqas and marwas being filled in, as in most cases farmers have preferred to enlarge the road or leave the new land uncultivated in order to avoid conflicts.

12. The *theft of pump motors* is a very critical problem that has long been identified. Our global survey found out that 26% of the pump stations had had their motors stolen at least once, of which 22% had their pumps stolen twice and 3% thrice. Theft is chiefly occurring in pump stations with a good road access and remote from houses and villages. Wherever the mesqa has been filled, farmers have no choice other than replacing stolen motors at a high cost. Although farmers have demonstrated a lot of creativity to prevent theft or make it more difficult, this scourge should be considered seriously and structural solutions found.

13. Farmers experiment frequent problems to find *spare parts* or to repair a number of shortcomings by themselves. This is illustrated by the on-farm interventions of the IIIMP project which, because of the reduced quality of the material used, resulted in many leakages. Although the contractor has the obligation to intervene during one year after reception of the works by farmers in case of leakage, in practice it may take a long time to obtain such an intervention. Smaller problems, often related to unfinished work, are also reported to contractors but not resolved, which makes farmers angry and creates unnecessary nuisance or harm to villagers. Some mechanism must be found to ensure 'after-sales service'.

14. The overwhelming majority of farmers did not know how much they would *have to pay annually*, and for how long, for the *tatweer* investment. Although the cost to farmers is individualized and depends on the final design at construction time, the costs range of the proposed improvements should be made clear from the beginning, as a means of building trust. More surprisingly, the financial burden corresponding to the imposition of this payment was very seldom mentioned by farmers as a cause of great dissatisfaction.

15. Because of the formal importance of coming up with adequate internal rates of return, both for the financing and the *economic evaluation of development projects*, the soundness of technical options and the quality of the material employed in construction is sometime negatively affected by the excessive weight given to economic analysis by development banks. The most blatant illustration of that state of affairs is the unfortunate reduction in the quality of works driven by the will to cut costs to improve the formal economic viability of the on-farm improvement projects associated with IIIMP. This has resulted in countless defects and failures in the distribution network that have angered farmers and undermined the project itself.[17]

The formal cost-benefit analysis carried out by project planners is of little relevance and farmers are, under certain conditions, eventually ready to pay for a technical innovation that may bring few of the benefits expected but which substantially decreases the drudgery of irrigation at tertiary and farm levels. This conclusion provides a very strong indication that collective (electric or mixed diesel/electric) pump stations, even stripped of promises of continuous flow and other benefits, could be proposed *'on-demand'*, with farmers sorting out whether their particular conditions (including location within the distribution system, physical characteristics, investment capacity, social cohesion, etc.) make such an investment *desirable*.

16. The clear evidence of a *demand for both mesqa and marwa level improvements* could fuel a demand driven project, whereby accredited contractors could propose farmers a range of possible improvements. Improvements at the on-farm level would be negotiated directly with the farmers, while construction of collective pumps would be supervised by the IIS, a crucial control point being the need to keep the installed pumping capacity in line with the area served, in order not to impact downstream areas. The success of these interventions would depend on their quality, which will determine the interests of neighboring farmers and the contractor in replicating the improvements.

However, not all settings are favorable to the implementation of collective PS. A zoning could identify the priority areas for offering improvement to farmers with a higher chance at succeeding; expectedly areas with higher demand would include areas along the main canals or along the head reach of branch canals that have good access to water; areas with long mesqas or marwas, or higher elevation; areas with groups of farmers with good relationships and making up between 25 and 40 feddan, etc. Under prevailing conditions of distribution by rotation between and within branch canals, the crucial factor is the number of days a PS can expect to have water and therefore to have a

[17] IFAD, which is funding that project, has reverted to its policy and requested higher quality standards.

pumping capacity high enough to serve the whole area. The attractiveness of the project to farmers is therefore linked to whether they will see their pumping capacity increased. The risk is to see improvement interventions increasing their capacity (by exceeding design capacity and not removing existing pump sumps) in order to gain the acceptance of farmers. This would mean that the gains in equity in the distribution of water at the tertiary level would be paralleled by losses in equity at the secondary level, with the situation of downstream farmers being worsened.

17. Ultimately, the IIP/IIIMP project is currently taken forward in a manner that is increasingly remote from the initial hypotheses and expectations. Continuous flow has not been established and there is no evidence of water savings or increases in productivity associated with the project; structural intervention at the branch canal levels have been discontinued and institutional building has been rather modest; official WUAs are frequently disconnected from the way the pump station is managed and maintained in practice; reduction in pumping time and costs at the pump station level have come together with improvements in equity among farmers on the same mesqa, but the project has failed to achieve a more equitable distribution at the branch canal level, and may even have worsened it as the pumping capacity of upstream farmers has generally increased. Individual pumps used to access water from both canals and drains, which should have been discontinued, are still everywhere to be seen. Yet, the improvement of water distribution at the tertiary and, maybe more so, on-farm levels through pressurized pipe networks keeps a degree of attractiveness in certain physical and social settings that have to be determined by the users themselves.

In such a situation it is debatable whether Egypt should go ahead with Improvement Projects as a priority and 'national project'. If improvement interventions have some private benefits to farmers that under certain conditions make them acceptable or desirable, it is dubious whether the limited collective gains achieved, notably in terms of unlikely water savings, warrant the public costs incurred (around 60% of the total investment in the optimistic case where farmers would be reimbursing their share). This is clearly a debate that has to take place at a higher level, considering the resources available and the ranking of priorities to be established by the state.

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